RESOURCE ALLOCATION FOR THE UNITED STATES NAVY ATTACK CARRIER STRIKING FORCE IN THE 1968-1980 PERIOD

by

James Francis Jenista, Jr.

Thesis submitted to the Faculty of the Graduate School of the University of Maryland in partial fulfillment of the requirements for the degree of Master of Arts
1967

APPROVAL SHEET

Title of Thesis: Resource allocation for the United States Navy Attack Carrier Striking Force in 1968 - 1980.

Name of Candidate: James Francis Jenista, Jr.
Master of Arts, 1967

VITA

Name: James Francis Jenista, Jr.

Permanent Address: 3938 Elm Avenue, Brookfield, Illinois

Degree and date to be conferred: Master of Arts, 1967

Date of birth: May 1, 1928

Place of birth: Chicago, Illinois

Secondary education: Lyons Township High School; June 1945

Collegiate institutions attended	Dates	Degree	Date of Degree
Illinois Institute of Technology	1945 & 1946	-	-
Bucknell University	1946	-	-
Cornell University	1946	-	-
Ventura College	9/59 to 2/61	-	-
U. S. Naval Postgraduate School	3/61 to 3/63	B.S. Mathematics,	March, 1963
University of California, Los Angeles	9/63 to 6/65	-	-
University of Maryland	8/65 to 9/66	M.A. Economics,	February, 1967

Major: Economics

Minor: Defense Policy

Positions held: Enlisted in U.S. Navy on 17 August, 1945.
Designated Naval Aviator on 20 May 1948.
Commissioned Ensign, USN on 17 December 1948.
Present rank is Commander, USN.

ABSTRACT

Title of Thesis: Resource Allocation for the United States Navy Attack Carrier Striking Force in the 1968-1980 Period.

James F. Jenista, Jr., Master of Arts, 1967.

Thesis directed by: William A. Niskanen, Ph.D.
Neil M. Singer, Ph.D.

The problem of efficient allocation of scarce resources occurs in industry and in military planning. Replacement schedules for existing production equipment can be analyzed for both organizations using the same techniques.

Replacement of the remaining World War II - built HANCOCK-class aircraft carriers is scheduled for the mid-1970 period. The hypothesis is tested that replacement can be made earlier than scheduled with no increase in cost. Two alternative replacement schedules are set forth, using conventional-power carriers in one and nuclear-power carriers in the other.

Methods of conducting a cost-effectiveness analysis of this type are discussed in some detail. The method of setting the alternatives equal in cost and measuring the resulting effectiveness is selected. Marginal effectiveness and its analysis are discussed.

The techniques for estimating system cost and adjustment of force levels to set them equal are illustrated with unclassified examples. Hypothetical scenarios postulated in order to allow force effectiveness to be measured are then described and illustrated.

Discussion of the results of the classified analysis is carried out in unclassified terms. It is emphasized that analysis of this type does not determine which alternative should be chosen. It provides the decision-maker with a logical presentation of the probable consequences of each alternative set forth for the analysis so that he may make a more efficient choice in his allocation of the resources at his command.

RESOURCE ALLOCATION FOR THE UNITED STATES NAVY ATTACK CARRIER STRIKING FORCE IN THE 1968-1980 PERIOD

by

James Francis Jenista, Jr.

Thesis submitted to the Faculty of the Graduate School of the University of Maryland in partial fulfillment of the requirements for the degree of Master of Arts

1967

ACKNOWLEDGEMENTS

Sincere appreciation is extended to the many persons in the Department of Defense, the Institute for Defense Analyses, The Center for Naval Analyses, and the University of Maryland, who provided assistance, suggestions, encouragement, and constructive criticism of the analysis presented here. It would be impractical to name them all, but a special debt of gratitude is owed to Drs. Niskanen and Singer, and Ed Sanders of IDA, for my immediate guidance during the past months. Above all, I can never adequately thank my wife, Sally, for shouldering the burdens of a large family so that the work could be completed. To her, and to my children, this thesis is dedicated.

TABLE OF CONTENTS

CLASSIFIED SUPPLEMENT

(Bound separately for U.S. Navy distribution)

LIST OF TABLES

LIST OF TABLES (Cont.)

LIST OF TABLES (Cont.)

LIST OF TABLES (Cont.)

LIST OF FIGURES

LIST OF FIGURES (Cont.)

CHAPTER I

INTRODUCTION

The problem of efficient allocation of scarce resources exists in some form in every industry.

Consider the Edge-Ring Division of Consolidated Corridors, Ltd. This firm produces a single output for consumption in a highly competitive industry. Its production process is shown in block diagram form in Figure 1.

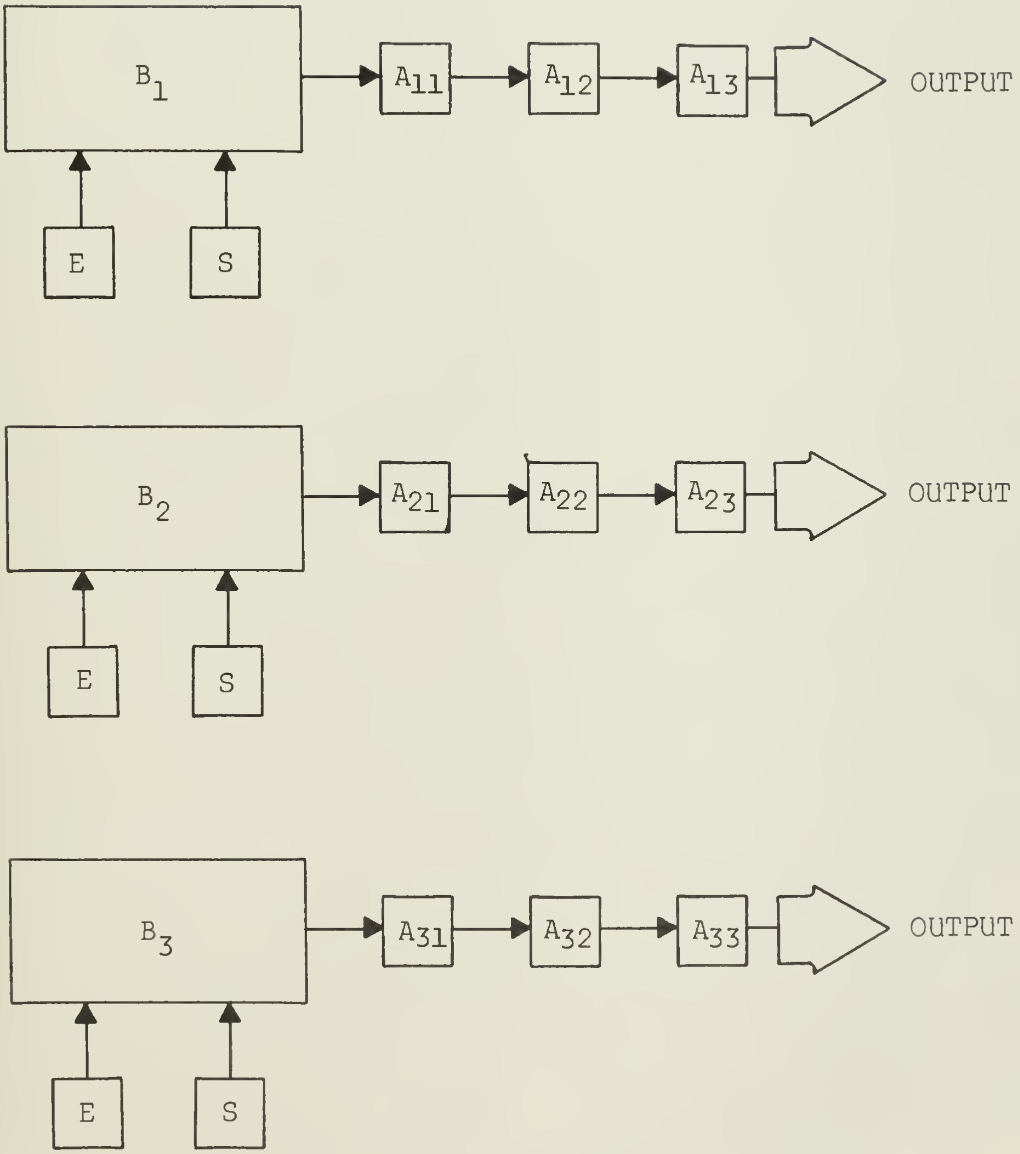
The plant has a number of B-machines, of varying ages and capacities. The process requires one B-machine connected with a set of the auxiliary machines labeled A_{11}, A_{12}, etc.. Certain inputs are provided by E and S; the quantity depends on the particular model B in use.

Production scheduling is further complicated by some incompatibilities; certain models of the A_{ij} cannot be connected with some of the B_i, or, if connected, will not operate with any degree of efficiency.

The production manager has been directed to submit his proposed program for replacement of outmoded and/or worn-out machines for the next few years. This program will be a complex one, since a number of factors must be taken into consideration. First, his budget is constrained by corporate headquarters. Within his budget limitations, he must attempt to produce the "best" possible output. The definition of "best" itself requires that some form of measurement of the desired qualities of the output must be found, and agreed upon by

FIGURE 1

EDGE-RING DIVISION PRODUCTION PROCESS



everyone concerned. Second, the fact that the industry is highly competitive means that other firms' threats to Edge-Ring's share of the market must be taken into consideration. This is especially true in the time-phasing of equipment purchases planned to take advantage of product improvements in their design. Finally, the possible loss of investment returns from other purchases which might be made with the capital funds available must be balanced against the expected gains from early investment in machinery with a greater capacity. One example would be the investing of capital funds in securities offering a high interest rate, and postponing the equipment purchase. Net revenue gain might be greater in this manner, although the possibility of competitive firms capturing Edge-Ring's share of the market could seriously affect the future revenue predictions. Uncertainty about future demand is a major factor in this decision; often the only source of this vital item is a subjective evaluation of the market.

Faced with a problem of such magnitude and complexity, the manager is greatly assisted by the proper use of the analytic tools of economic decision-making. Proper analysis will allow him to compare the relative merits and disadvantages of any proposed plan or set of plans before coming to a decision on which one to propose. The analyst must not only rank the alternatives in terms of output, but must indicate the marginal cost involved in accepting each alternative, as well as the marginal cost of rejecting the others.

Military decision-making in the Department of Defense encounters very much the same sort of problems. Economic analysis in a military context is critical for two very important reasons. The

resources available to the nation as a whole, and therefore for its defense, are limited and require efficient allocation to their alternative uses. At the same time, the cost of failure to provide adequate defense may be incalculable. The risk associated with any specific level of defense by virture of the uncertainty of future world events further complicates the problem. In terms of our hypothetical firm, it compares with the uncertainty of predicting future demand.

The United States Navy attack carrier striking forces are charged with production of a single, but multidimensional, output, described by their mission:

> ". . . to serve as floating air bases; to engage any forces afloat and ashore which threaten our control of the sea; and to support other forces."[1]

The force is currently composed of sixteen aircraft carriers, fifteen of them in commission, and seventeen carrier air wings. Force elements are listed in Table 1 at the end of this chapter. The aircraft currently in use or under development are listed in Table 2.

Efficient allocation of resources in the attack carrier striking force is directly involved with the planned replacement of its capital equipment. The problem is directly analogous to that facing the Edge-Ring Division; each carrier and its associated air wing forms a production unit, requiring both escorts and support ships in order to function. Some combinations of aircraft and ship are impractical, or relatively inefficient. The scarce resource is

---

[1]Frank Uhlig, Jr. (ed.), Naval Review 1962-1963 (Annapolis, Md.: United States Naval Institute, 1962), p. 219.

the assigned share of the National Defense Budget; maximum efficiency in its allocation is vital to our nation's survival.

The first five carriers listed in Table 1 were originally constructed as ESSEX-class carriers during and after World War II. A number of modifications have been made to these carriers in order to adapt them for use with modern jet aircraft.[1] Despite these extensive changes, these carriers are approaching obselescence.

As the HANCOCK-class carriers become older, they require continuous repair and costly improvement to keep them in operation. Certain of the newer aircraft are unable to operate from this class, notably the F-4 and the F-111B, the current and next-generation fighter aircraft.[2] The currently assigned fighter, the F-8 Crusader, was first delivered to the fleet in 1960. A modification program is under way to extend the life of some of these aircraft for use aboard the HANCOCK-class.[3]

The size of modern jet aircraft is another important factor which affects the decision to retire the HANCOCK-class. Ships

---

[1]The most readily observed changes are an angled deck for landing, enclosed bow, number three elevator moved to the deck edge, steam catapults, and the mirror landing system. Internal modifications are numerous and continuing. The U.S.S. ORISKANY (CVA-34) is equipped with the Naval Tactical Data System, an automated, computer-assisted air defense system which will ultimately be installed on all attack carriers. Former ESSEX-class carriers with the modifications listed above are now considered the HANCOCK-class; their conversion is referred to as the 27-C conversion. Source: Raymond V. B. Blackman (ed.), Jane's Fighting Ships, 1965-1966 (New York: McGraw-Hill, 1965), p. 324.

[2]U.S., Congress, House, Subcommittee of the Committee on Appropriations, Hearings on the Department of Defense Appropriations for 1967, 89th Cong., 2nd Sess., 1966, Part 1, p. 151.

[3]Naval Aviation News, June, 1966, p. 28.

designed to operate 130 aircraft in World War II are limited to some 80 of the current models at the same percentage utilization of available parking space.[1] The increased ordnance and fuel consumption rates require greatly increased storage and handling capacity, or more frequent replenishment.[2]

The Navy Department is concerned with plans for replacement of its outmoded capital equipment, just as the production manager of the Edge-Ring Division was. The older B-machines (carriers) cannot operate efficiently with modern fighters and attack aircraft (the A_{ij}). As demand increases, the older machines simply cannot maintain the pace. There is no question of usefulness of the equipment, but rather whether there is a more efficient use of the scarce resources available.

A replacement schedule for the HANCOCK-class attack carriers has been established. It calls for retirement of one in fiscal year 1969, when the JOHN F. KENNEDY (CVA-67) joins the fleet, and one more by end fiscal year 1970, when the MIDWAY-class modernization will be completed. The remaining three will be retired as new construction is delivered, starting with the approved fiscal year 1967 nuclear carrier.[3] Under the assumption of additional

---

[1]Blackman, op. cit., p. 323.

[2]U.S., Congress, House, Hearings, 1966, p. 581.

[3]This carrier is a new design, essentially an AMERICA-class ship with a two-reactor nuclear power plant. It is sometimes referred to as the CVAN-2E, for "Nuclear Attack Carrier, 2-reactor, Enterprise hull," or by its hull number, CVAN-68.

construction of two more nuclear carriers of the same class at two-year intervals, the replacement plan would appear as outlined in Table 3 at the end of this chapter. Note that replacement of the MIDWAY-class, which should begin shortly after retirement of the last HANCOCK-class ship, has been omitted. The modernization program being undertaken will extend the life of this class into the 1980's; therefore they can be considered a constant element of the force for this analysis.

The question of whether this planned replacement schedule is optimal leads to the following

HYPOTHESIS: The remaining HANCOCK-class attack carriers can be retired earlier than currently planned. Cost savings will more than offset expenditures for early replacement.

Early replacement implies an accelerated building schedule. While it is technically possible to construct up to three carriers simultaneously in U. S. shipyards, the manpower limitations which exist in the military services today would prevent the manning of all these ships with their initial crews at the same time. Second, construction cannot begin until the Congress appropriates the funds, an annual process. Third, it is more expensive to build more than two carriers simultaneously than sequentially, in part because the available ways can hold just two at one time. Adding more ways or contracting with another shipyard would add to the cost. Taking these considerations into account resulted in selecting the alternatives listed in Table 3 as feasible alternatives to the basic plan.

The new construction is currently planned as nuclear power. Alternative One would substitute conventional power for the two additional carriers, while Alternative Two retains nuclear power; both are on an accelerated building schedule. The alternatives are hypothetical, of course; they are selected to expose the sensitivity of the hypothesis to the assumptions made. Both alternatives involve early replacement of the last two HANCOCK-class, and will result in force differences, especially in the 1973-1975 period.

The alternatives outlined provide a total of three different ways to accomplish the same goal, modernization of the attack carrier striking force. Each of these alternatives must be carefully analyzed before any conclusions can be drawn regarding their relative value. The same factors which affect the Edge-Ring's replacement schedule enter here; budget constraints, effectiveness in competition with potential opponents, and cost implications of differing time schedules. An analytical model will be constructed in the next chapter in order to perform the comparison.

TABLE 1

ATTACK CARRIER STRIKING FORCES

Hull Number	Name	Commissioned	Air Wing[a]
CVA 14	Ticonderoga	1944	CVW 5
CVA 19	Hancock*	1944	CVW 21
CVA 31	Bon Homme Richard	1944	CVW 19
CVA 34	Oriskany	1950	CVW 16
CVA 38	Shangri La	1944	CVW 10
CVA 41	Midway*	1945	Out of Commission--Shipyard Overhaul
CVA 42	Franklin D. Roosevelt	1945	CVW 1
CVA 43	Coral Sea	1947	CVW 15
CVA 59	Forrestal*	1955	CVW 8
CVA 60	Saratoga	1956	CVW 3
CVA 61	Ranger	1957	CVW 2
CVA 62	Independence	1959	CVW 7
CVA 63	Kitty Hawk*	1961	CVW 11
CVA 64	Constellation	1962	CVW 14
CVA 66	America*	1965	CVW 6
CVA 67	John F. Kennedy	--	Under Construction
CVAN 65	Enterprise*	1963	CVW 9
			RCVW 4, 12

*Legend and note on page 10.

TABLE 1 - Continued

Legend:	
CVA	Attack Carrier
CVAN	Attack Carrier, Nuclear Power
CVW	Attack Carrier Air Wing
RCVW	Attack Carrier Air Wing, Refresher Training
Midway*	Asterisk indicates class-name ship

[a]Air wing-ship assignments are not fixed, but vary with deployment and overhaul schedules.

Source: Jane's Fighting Ships 1965-1966, 1965, pp. 319-324; Naval Aviation News, January 1965 to July, 1966 editions.

TABLE 2

ATTACK CARRIER BASED AIRCRAFT[a]

Model	Crew	Weight	Dimensions		Power Plant	Speed	Remarks
			Span	Length			
ATTACK							
A-1	1	17,982	50'	39'2"	R-3350-26WD (1)	350	Del 1953
A-3	3	70,000	72'6"	75'9"	J57-P-10 (2)	650	Del 1957
A-4	1	17,500	27'6"	41'4"	J52-P-8 (1)	700	A-4F 1966
A-6	2	38,750	53'	53'3"	J52-P-6 (2)	650	Del 1961
A-7	1	33,000	38'	46'	TF30-P-6 (1)	700	Del 1966
FIGHTER							
F-4	2	45,000	38'5"	58'3"	J79-GE-8 (2)	M2+	Del 1959
F-8	1	25,500	35'8"	54'6"	J57-P-20 (1)	M2	Del 1960 Mod 1966
F-111B	2	68,000	70'	67'	TF30-P-3 (2)	M2.5	Del 1970
RECONNAISSANCE - ECM							
RF-4	2	45,000	38'5"	58'3"	J79-GE-8 (2)	M2+	Del 1965
RF-8G	1	24,400	35'8"	55'3"	J57-P-20 (1)	M2	Mod RF-8A Del 1966
RA-5C	2	76,500	53'	76'6"	J79-GE-8 (2)	M2	Del 1964
EA-6	2	38,750	53'	53'3"	J52-P-6 (2)	650	Del 1966
WARNING							
E-1	4	26,966	72'4"	45'4"	R-1820-82WA (2)	250	Del 1958
E-2	5	49,500	80'7"	56'4"	T56-A-8 (2)	300	Del 1964

TABLE 2 - Continued on next page.

TABLE 2 - Continued

Model	Crew	Weight	Dimensions		Power Plant	Speed	Remarks
			Span	Length			
ASW - RESCUE							
SH-3D	4	17,300	1-62'	54'9"	T58-GE-8 (2)	200	Del 1965 Helo
UTILITY							
C-2	2(40)	49,500	80'7"	56'4"	T56-A-8 (2)	300	Del 1965 Transport

[a]James C. Fahey (ed.), The Ships and Aircraft of the U.S. Fleet (eighth edition; Annapolis, Md.: United States Naval Institute, 1965).

TABLE 3

HANCOCK-CLASS REPLACEMENT PROGRAM

CLASS	1968	1969	1970	1971	1972
Current Plan					
HANCOCK	5	4	4	3	2
MIDWAY	2	2	2	3	3
FORRESTAL	4	4	4	4	4
AMERICA	3	4	4	4	4
ENTERPRISE	1	1	1	1	1
CVAN-2E					1
Alternative No. 1(changes only)					
HANCOCK					
AMERICA					
CVAN-2E					
Alternative No. 2(changes only)					
HANCOCK					
CVAN-2E					

TABLE 3 - Continued

1973	1974	1975	1976	1977	1978	1979	1980
2	1	1	0	0	0	0	0
3	3	3	3	3	3	3	3
4	4	4	4	4	4	4	4
4	4	4	4	4	4	4	4
1	1	1	1	1	1	1	1
1	2	2	3	3	3	3	3
-1	-1	-1					
+1	+2	+2	+2	+2	+2	+2	+2
	-1	-1	-2	-2	-2	-2	-2
-1	-1	-1					
+1	+1	+1					

CHAPTER II

METHODOLOGY

A chapter on methodology should logically begin by making it clear just what we are trying to accomplish. We are confronted with a system, the Attack Carrier Striking Force. Our goal is to analyze the effects of changes in the system; hence the term system analysis.

The purpose of the analysis is to assist in somehow maximizing a return on our investment, or alternatively, minimizing the cost of obtaining a specified return. As such, it is imbedded in a spectrum of analytic techniques, ranging from the classical theory of a firm attempting to maximize profits--the difference between a discounted stream of revenues and a discounted stream of costs--to the field of pure operations research, where the attempt is to obtain maximum effectiveness from a specific set of resources.

The profit maximization problem can be expressed entirely in terms of dollars, while operations research has no limitations on the unit of measure. Between these limits lies the system analysis or, more precisely, cost-effectiveness analysis with which we are concerned.

Military cost-effectiveness analysis is <u>not</u> a decision rule, but an economic tool designed to reduce the level of uncertainty in the final decision. The decision maker is assumed to be knowledgeable in the military aspects of the problem. Given a statement

of the specific question, he would be capable of making some sort of decision without the analysis, based on his past experience. But the more he knows about the problem, especially about the costs involved, the better will be his decision.

> "A cost analyst operates on the simple faith that a decision maker will make a better decision if he is aware of the costs of his action, regardless of what kind of analysis or professional judgment supports the decision. Such faith has gone a long way; the time-phased display of weapon systems and costs by major mission has probably been the most important change in management techniques made by the present Administration. I am still surprised how many problems are solved by knowing the costs of the alternatives, how many dominant cases are apparent, how many arguments over specifications and policies are apparently irrelevant. An awareness of costs also shapes the program review and study process by focusing attention on the areas of major resource commitment."[1]

The analysis itself contains five essential elements:

1. An objective to be performed.
2. Alternative ways to meet the objective.
3. Resource costs of the alternatives.
4. A model relating 1, 2, and 3.
5. A criterion for choosing the preferred alternative.[2]

The objective of the Attack Carrier Striking Force is set out in its mission, quoted in Chapter I. There are a number of tasks which may be performed in carrying out that mission, and each alternative considered must be capable of accomplishing each of these tasks.

---

[1] Address by William A. Niskanen, Jr., Director of Special Studies, Office of the Assistant Secretary (Comptroller), Department of Defense to the Joint Conference of the Canadian Operations Research Society and the Operations Research Society of America; Montreal, Canada: May 28, 1964.

[2] See, e.g., Hitch and McKean, <u>The Economics of Defense in the Nuclear Age</u> (New York: Atheneum, 1965), Chapter 7.

The alternatives selected are variations in time-phasing of essentially the same force structure. There are probably a great many other ways to meet the stated objective, some of them competitive under certain conditions. An example would be the Tactical Air Forces of the United States Air Force. The tasks of interdiction, air superiority, and close air support are common to both forces. Studies of the most efficient mix between these forces are appropriate tasks for systems analysts, but are addressed to a decision level higher than that of this paper.

Resource costs of the alternatives are all those costs chargeable to the alternatives. These are not just the cost of the hardware to be purchased, but the total systems cost of buying hardware and support equipment, training and supplying personnel to operate the system, the annual costs of operating and repairing the equipment, and the costs of replacement of destroyed or overage items. The length of the planning period selected is seen to be an important factor in the costing. It affects the operating costs, of course; but at the end of the period the remaining useful life of the system must be accounted for. An allowance for salvage value of the equipment, expressed as the present value in its next best use (its "opportunity cost", in economic terms) must be subtracted from the total. This salvage value may in fact be just the cost of replacing the equipment with another one of the same type. In any event, care must be taken to ensure that such items as remain in the inventory at the end of the planning period do in fact retain a military worth or effectiveness at that time

before assigning a value; prediction of the state of the art and of the need for a system in the future is fraught with uncertainties and the chance of statistical error.

Considerable effort has been put into solution of the problems of costs and of investment policies for equipment subject to replacement.[1] The particular cost technique selected must be tailored to the scope of the study, the available data, and the time and manpower constraints of the study groups. Inaccurate or unsupportable predictions may be worse than useless; they may reinforce decisions which might better have not been made at all.

A model of the problem is basically an abstraction of the real world designed to cope with the myriad variables inherent in any system in such a way that only those variables especially relevant to the decision at issue need be considered.

Models may take a number of forms, from simple graphs to complex equations to a full-scale maneuver of actual forces. The purpose is to simulate real or expected conditions in such a way that the outcome predicted by the model will have some validity when applied to the real world system.

One very important part of any economic analysis, and particularly of any military cost-effectiveness analysis, is the examination of the effects of allowing other factors to vary. The

---

[1] A. Reisman, and E. S. Buffa, "A General Model for Investment Policy," Management Science, VIII (1962), pp. 304-310.

sensitivity of the results to variations in the factors assumed constant give some indication of the consequences of a poor prediction, or a wrong choice. The major effect of sensitivity analyses is to reduce the level of uncertainty for the decision maker.

With the objective in hand, the alternatives and their costs defined, and a model constructed and tested for sensitivity, the system is ready for evaluation. But that evaluation must be measured against some sort of standard; what is needed is a criterion or measure of effectiveness, a term usually abbreviated to MOE. The choice of the MOE is critical to the outcome. An interesting commentary on the subject of choosing appropriate measures of the effectiveness of a system was delivered at a Symposium on Cost-Effectiveness Analysis sponsored by the Washington Operations Research Council in Washington, D. C., on 14 June 1965:

> ". . . The choice of these measures is the most difficult <u>unique</u> problem of cost-effectiveness analysis. The appropriate measure should have two characteristics: First, and most important, it must be relevant; preferably, but less important, it must be measurable. These objectives are often conflicting. The most relevant are often very difficult to measure and vice versa. The analyst's first challenge, therefore, is to choose a better combination of relevance and arithmetic than that exhibited by most political strategists, and, for that matter, by all too many operations analysts.
>
> Let me give you some examples of the problems in choosing proxy measures and the effects of maximizing on such proxy measures. You are probably familiar with the story about the manager of the Soviet nail factory, who was initially given a measure of merit for his output in terms of the total <u>weight</u> of the output of his establishment. Like a good bureaucrat, he maximized on this explicitly stated objective and turned out only huge railroad spikes. As a result of having a surplus of railroad spikes, his objective function was changed to maximize the total <u>number</u>

of nails he produced. In a very short time, he was able to switch over to complete production of brads, tacks, and staples. Because the Soviets have chosen not to evaluate their output by market criteria, they try to define the measure of effectiveness for a particular establishment in some physical terms. In this example, maximizing on these physical terms led to an activity which was inconsistent with the interests of the higher level decision makers.

The construction of Federal buildings presents the same problem. The contracts for most Federal buildings are let on a fixed price, competitive bid basis, primarily on the basis of cost per square foot. As a result, this has led to prison-like structures, with minimal outside window space and huge rooms inside--a generally depressing environment. One of the most interesting, not to say timely, expressions of this problem was formulated about 120 years ago by Jeremy Bentham, the English utilitarian. He wrote a short essay on what he considered to be the optimal prison, and included a drawing to illustrate his conclusion. This prison has 5 sides, it is 5 stories high, and has an inner courtyard!"[1]

Before any criteria can be applied to competing alternative systems, the systems must somehow be set equal. Clearly, in terms of cost-effectiveness, if two alternatives are equal in cost, then that which is more effective is the preferred alternative. Equally acceptable is the less costly of two alternatives equal in effectiveness. If two alternatives exhibit both different costs and different levels of effectiveness, we have no basis from which to judge; or, rather, we have too many bases for judgment. The purpose of the analysis is to reduce the uncertainty for the decision maker; therefore equality must exist in one or the other.

---

[1]William A. Niskanen, Jr., U. S. National Security Objectives and The Choice of Measures of Effectiveness (Internal Note N-30(R), Economic and Political Studies Division, Institute for Defense Analyses, Arlington, Va., 1965), pp. 4-5.

The mission of the attack carrier striking forces is a single one, but it is multi-dimensional. Because of the difficulties in defining effectiveness adequately, and of measuring the effectiveness once defined, as well as the sensitivity of the results to the situations and world events postulated, the equal-effectiveness method is somewhat less preferable. On the other hand, costs are at least transformable to a single dimension. In addition, costs are expressed in units familiar to laymen, and the implications of a dollar spent or saved are easily grasped. The evaluation of the resulting level of effectiveness for each alternative is left, in part, to the decision maker. Our assumption that the decision maker is knowledgeable in the military aspects of the problem merely serves to reinforce the choice of equal-cost alternatives.

One danger in equal-costing is that a given alternative may be forced to operate at a level less than "optimal" for its structure. If one alternative is more expensive, but exhibits greater effectiveness, it may well be that the sacrifice of effectiveness caused by reducing its cost to equal that of the other alternatives may cause it to become less preferable. One way around this possibility is to examine the effects of increasing the cost of the other alternatives and the resulting effectiveness. In a crude manner, this amounts to taking the first derivative of the alternatives with respect to effectiveness and examining their slopes; it is the marginal effectiveness at the force level postulated.

An example will serve to illustrate; in Figure 2, the costs of two alternatives are plotted as a function of effectiveness. For each system, both marginal costs (MC) and average costs (AC) are plotted. Just as in a firm, the optimum level of performance occurs where MC=AC, and if the price (demand) is suitable, this is the desired (effectiveness) level. For any other demand, the most favorable position to operate is on the MC curve. This, in effect, forms the supply curve for the system. Clearly, at the optimum level of performance for system A, represented by C_0 on the ordinate, system B suffers in an equal-cost comparison, while the reverse is true at C_1. The decision on which system is "best" is a function of the overall effectiveness level (demand) to be maintained during the period in question.

Another factor to be kept in mind is future changes in force requirements. If E_{AO} happened to be satisfactory for the planning period under study, system A would be preferred. On the other hand, if conditions were such that a growth capability to some level beyond E_{AB} was anticipated as a future requirement, and if system B had a significant useful life remaining at that time, its selection would be preferred. Here, the choice of the length of the planning period enters as an important variable. Although the selection of a period for study is sometimes dictated by factors outside the study, it is more often arbitrary; in either case the sensitivity of the results to changes in its length must be tested.

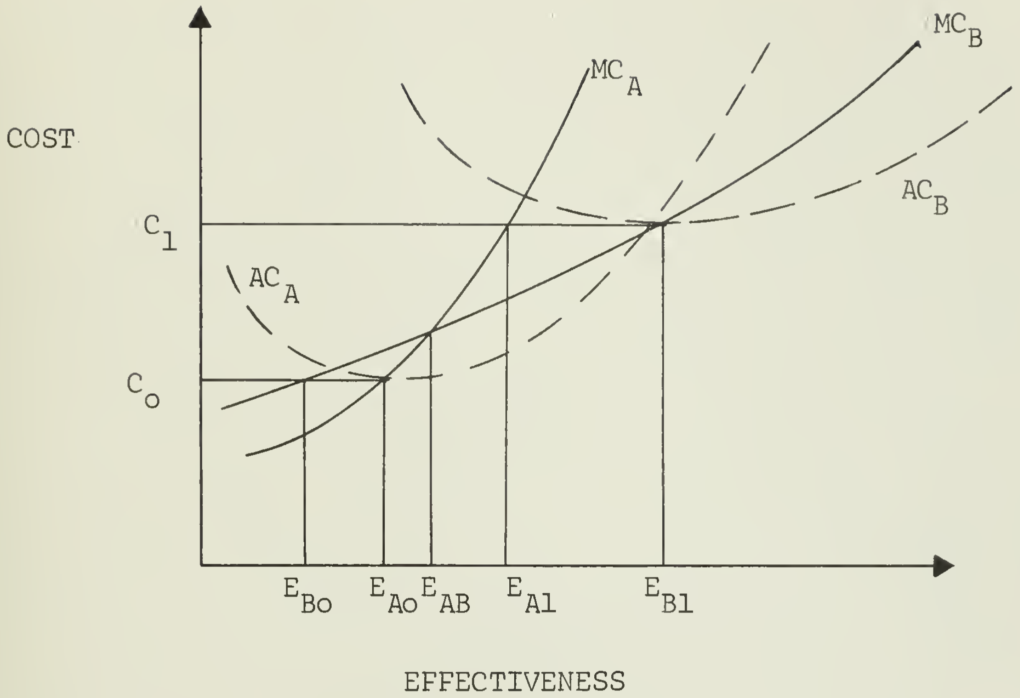


Figure 2a

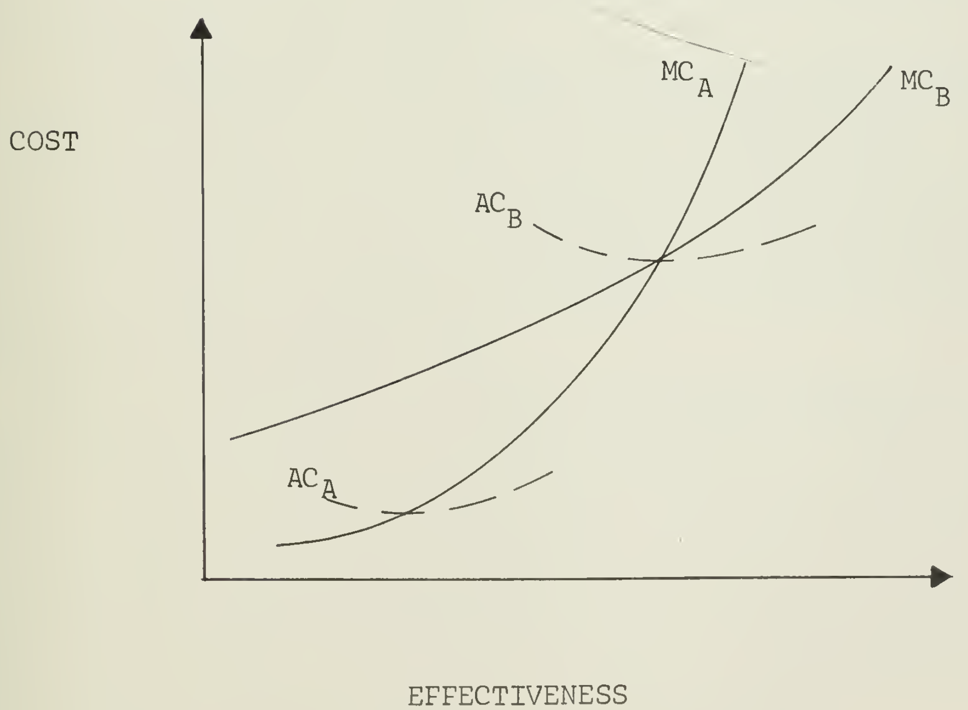


Figure 2b

Figure 2b illustrates another possible outcome. Here, System A displays greater effectiveness at every cost level up to the optimum for System B; even at this level, effectiveness is equal. The importance of the location of the demand curve and the future requirement beyond the planning period under consideration are now the controlling factors. It may well be that additional study in an attempt to predict demand will be required before a decision can be made. This sort of result is precisely what the present study is designed to do. If it correctly illustrates the consequences of any decision for the decision-maker, it helps him either make up his mind on an alternative, or decide to seek more data before coming to any conclusion about the alternatives. It has served to reduce the uncertainty for him, and illuminate other factors which affect the choice.

For the hypothesis of this paper we are given the objective, the assigned mission of the Attack Carrier Striking Force. Three alternatives have been postulated, designed to examine the implications of a number of factors, principally the time-phasing of replacement of the HANCOCK-class.

Costs of the alternatives will be expressed primarily in terms of marginal costs; that is, the difference in costs between the basic plan and the two alternatives. Since each alternative is a time-phased plan, and comparison will be made on an equal-cost basis, the costs will differ from year to year in each case but will sum to zero when totaled for the alternative.

Cost of the basic plan will be computed as a reference mark,

The alternatives will first be assembled at their optimal level, then adjusted in force level to arrive at equal-cost conditions.

Since the adjustment in cost affects the effectiveness of the force, the cost adjustment will be made by varying the number of strike aircraft purchased. The planned air wing composition is set up in order to optimize the effectiveness of each carrier; therefore a different number of strike aircraft will result in operation at some level less than optimum. This is a result of the congestion on the flight deck; with a greater number of aircraft on board, refueling and rearming take more time. Moving parked aircraft to allow launch and recovery operations also increases the time between successive launches. The total result is a somewhat reduced strike capability <u>for each individual aircraft</u>. In the same manner, reduced deck load contributes to an increase in strike capability for each aircraft, but a smaller total capability of the whole force. In short, the force will not be operating at its optimum level. To test the marginal effect of performance away from optimum levels, additional adjustments will be made to bring all three alternatives to equal cost at each of the three cost levels.

The actual costs will be a time-phased stream of costs, including investment, training, operation and maintenance, and a salvage value at the end of the period. Details are covered in Chapter III. These are peacetime costs, since the purpose of the paper is to study the peacetime cost of providing wartime effectiveness in performing the assigned mission.

The additional wartime costs of any specific contingency will tend to be of minor concern. For example, it is estimated that the cost of United States forces in Korea over and above the normal cost of such forces if no action was taking place was approximately five billion dollars in the fiscal year 1951/52, about 11 percent of total United States expenditures for major national security programs that year.[1]

The implications of the timing of the alternatives will be examined by discounting the time-phased stream and collapsing the total systems cost to a single figure.

> ". . . , [I]n the case of the cost streams, even though costs are incurred at different times in the future, they can be weighted, summed, and reduced to single cost coefficients for each system. This is because a measurement of time preference is available which allows the annual increments of costs to be added. This is the preference of the economy for a dollar today versus a dollar tomorrow. In slightly different terms, the analyst weights future expenditures according to the time preference of the economy for command over resources -- the things dollars can buy -- in the near future versus command over resources at some later date. This time preference is expressed by the rate of interest that must be paid on borrowed funds. Such funds allow one to obtain command over resources now rather than at some future time. The technique used to weight and then sum the cost streams is known as discounting."[2]

Discounting for military expenditures is a measure of the relative importance of the system being purchased over the systems, either similar or dissimilar, which must be postponed or sacrificed

---

[1] U.S., Congress, House, Committee on Foreign Affairs, Hearings, 82nd. Cong., 2nd Sess., 1952, p. 359.

[2] James G. Abert, "Structuring Cost Effectiveness Analyses," Logistics Review and Military Logistics Journal, Vol. II, No. 7, 1966, p. 24.

in order to pay for the alternative. This will always be true under a budget constraint, even though the natural forces of supply and demand which exist in the private sector do not operate in the military environment to force restraint on expenditures.

Discounting is applied by using the function such that the weight attached to expenditures in the i^{th} year is $\frac{1}{(1+r)^i}$, where r is the interest rate. The present value of a time-stream of expenditures is thus:

$$P.V. = \sum_{i=o}^{n} \frac{C_i}{(1+r)^i}$$, where $(n+1)$ = number of years

covered in the study, and C_i is the cost in the i^{th} year.

One assumption over which a great deal of controversy exists is the rate at which expenditures are discounted. The rate is a function of the interest rate in the private sector, since the alternative allocation of the defense dollar is to the private sector. For most purposes a rate of 10%, representing a reasonable marginal rate of return before taxes on capital in the private sector may be used. Sensitivity to the rate will be tested by using two other rates as well; zero and 15%. It is impractical to assign a rate much higher than 15% for useful evaluation.

> "Another question concerns discounting cost streams "to take account of risk". Loading the discount rate with a factor "for risk" is quite perverse if it is intended to correct for doubts about the relative <u>cost</u> estimates in the systems studied.
>
> This is shown by considering two estimated cost streams for producing a given effectiveness. Suppose we know from empirical evidence that cost estimates for the farther-future become less reliable. Applying a discount rate to streams of single-valued, annual cost estimates reduces remote costs more than early costs. The discounted

> operation thereby biases choice toward projects with relatively large later cost estimates, the more uncertain alternatives. The bias would be still stronger if an attempt is made to account for differential estimating reliability among entire streams by discounting riskier cost streams at higher rates."[1]

The model to be used is the force structure planned for the 1968-1980 period. It includes the carriers and their air wings, plus escorts and support (underway replenishment) ships. The forces will be set up in the costing process, then exercised in a postulated conflict situation to evaluate their effectiveness, as measured by the criterion selected. The model itself is an abstraction from reality, since a number of assumptions must be made and adhered to for the evaluation. It was pointed out earlier that the real world force is affected by so many variables that an attempt to take them all into account would lead to endless frustration and the high probability that the problem would have occurred long before the solution was obtained. The intent is to draw a set of boundary lines around the problem in such a way that what is left inside is still free to vary, but to an extent which can be analyzed and reported on within the limitations of the student's time and knowledge. The primary assumptions are:

1. Basic replacement schedule will be one new CVAN-2E every two years, starting in 1967. This assumption was discussed in Chapter I.

2. Only AMERICA-class and CVAN-2E class carriers will be constructed. It is known that at least one new design for a

---

[1] N. V. Breckner and J. W. Noah, Costing for Systems Analysis, CNA Research Contribution No. 21, (Washington, D. C.: Center for Naval Analyses, The Franklin Institute, 1966), pp. 10-11.

carrier is being proposed, but the examination of all possible designs would extend the scope of the analysis beyond its intended boundaries.

3. The MIDWAY-class will be operated throughout the study period without replacement. The extension of the MIDWAY-class into the 1980 period was discussed in Chapter I.

4. The force level will remain at 15 carriers in commission and 17 air wings. The Secretary of Defense force structure proposals have fluctuated in the past, down to 13 carriers in 1965. His proposals for the immediate future call for a reduction in the number of air wings compared with the number of attack carriers.[1] This is proposed partly because a carrier in overhaul cannot operate with its air wing, and this wing is thus free to operate with other carriers. Because the effectiveness scenarios postulated would be complicated by their timing with respect to the carrier overhaul schedule, and because predictions about the need for attack carrier striking forces, and therefore their structure in 1980 are almost impossible in 1966, the existing structure will be retained. Uncertainty about requirements as a result of current operations in Southeast Asia contributes to the decision to hold force level constant.

5. Only aircraft now in existence or under development will be considered. It is recognized that several of the aircraft now in use will ultimately be replaced by new designs which have not

---

[1] U. S., Congress, House, Hearings, 1966, p. 150.

yet progressed to the drawing board. In order to analyze the question posed, an air wing must be placed aboard each ship, and its effectiveness evaluated. The effect of using current designs is twofold; first, costs are known or can be reasonably forecast. Second, performance data is available from which effectiveness of the alternatives can be calculated. Increases in cost for newer designs would certainly be accompanied by increases in effectiveness, but the trend should be evenly spread throughout the force, so that relative ranking of the alternatives would not vary.

6. 1966 Costs are assumed for the planning period. Estimates of all factors; investment, operations, maintenance, training, etc. have been made for the current year. The assumption is that cost trends and/or inflation will magnify the size of the total systems cost, but will affect each of the alternatives equally. The sensitivity test of the discount rate would have a similar effect as applying price trend factors to each year's expenditures, although the effects on total cost of increasing discount rate and increasing price trend are opposite.

7. Technology will be held constant. This assumption relates back to ship and aircraft designs, as well as the possiblity of developing a completely new substitute for the whole force. This assumption affects aircraft costs most significantly, because the observed effect in the past is that aircraft unit investment costs would decline as total quantity purchased increases, but continual improvement in the design of the aircraft and changes in the installed equipment force a growth in price instead. Forcasting future inventions is almost as hazardous as forecasting future peace

and prosperity; therefore the world of 1966 will be chosen instead.

The measure of effectiveness to be used to evaluate the alternatives is difficult to specify. Carrier aircraft can perform a variety of missions, from nuclear attack to recovery of astronauts; no single measure can adequately cover all tasks. On the other hand, attack carrier striking forces exist to project our striking power to wherever it is needed. Viewed in this light, the functions of air defense, anti-submarine defense, rescue, etc. serve to support and maintain the capability to deliver strike ordnance where it is needed. The mobility of the force is used to transit to the area of conflict, to assist in presenting a more difficult target for the enemy, and to allow replenishment to be conducted away from the area of battle. It seems logical, therefore, to select the total weapon delivery capability of the force as the primary measure of effectiveness. This will be defined as the total delivery capability available to a theater command throughout the course of a postulated war situation. In this way, the effects of mobility, response time, and defense capability while operating can be measured in terms of their contribution to the primary MOE. Support ship requirements will also be calculated as a chargeable item for each alternative.

Since the MOE is extremely sensitive to the location and duration of the conflict, two separate scenarios are postulated, with different characteristics. The implications of the difference in scenarios, plus additional variations used to test sensitivity, are discussed in Chapter IV.

In summary, then, we have defined the objective and selected the alternative. A number of critical assumptions have been made about the model, and significant sensitivity tests outlined for each step of the analysis. The following two chapters will discuss the costing and effectiveness--measuring parts of the analysis, respectively.

CHAPTER III

COST ANALYSIS

Actual force structures and cost estimates are classified. This chapter will describe the analysis technique, using unclassified data or hypothetical examples to illustrate the procedure.

There are six steps in the cost analysis. They are:

1. A determination is made of the time-phased inventory of tactical aircraft and ships the Navy will have in the 1968-1980 period, applying the assumptions of Chapter II.
2. By the same process, the time-phased inventories of Alternatives 1 and 2 are determined.
3. The total-systems cost of the basic plan is estimated.
4. Cost differences (marginal costs) for Alternatives 1 and 2 are derived and summed.
5. Adjustments are made to the force structures of the three alternatives to arrive at a set of equal-cost alternatives.
6. A sensitivity analysis is performed.

Each of these steps will be described in turn. The application of the technique to the classified problem is shown in Appendix B.

COST ESTIMATION

One problem with cost estimation is that the term means different things to different people; in particular, it means much more to an economist analyzing the effect of buying or not buying a particular set of equipment than it does to the accountant

who happens to be concerned with the actual purchase only. The economist is concerned with this, of course; but beyond the purchase lies the years of service; the direct charges which can be assigned for its operation and repair; pay of the operators of the machine; and indirectly, the share of the cost of running the "front office," which is necessary if the machine is to perform at all. These last, the overhead costs, are extremely difficult to assign on any systematic basis. It is clear, of course, that there is considerable room for disagreement over any estimate of cost, regardless of its source or intended purpose.[1] For the analysis at hand, it is important to the extent that the estimates arrived at effectively represent the relative cost of the alternatives being examined, not the total figure it might add up to.

The cost estimate for any single ship or type of aircraft in the force structure is a time-phased stream of annual expenditures over the period 1968-1980, and consists of investment, annual operating costs, and a salvage value in 1980. Investment includes initial purchase and outfitting as well as ship overhaul costs occurring during the year of overhaul. Annual operating costs cover fuel and ammunition expenditures, plus such items as overhaul allowance, spare parts and special equipment, pay and allowances for the crew, replacement crew training, etc. The salvage value of a ship or aircraft is calculated on the basis of expected

---

[1] J. Maurice Clark, Studies in the Economics of Overhead Costs, (Chicago: The University of Chicago Press, 1923), Chapter III, et al.

remaining useful life, and is expressed as a percentage of the cost of purchasing an identical replacement. Point estimates of all costs are used, expressed in 1966 dollars. No attempt is made to forecast trends, or to estimate a confidence interval for future expenditures.

Costs are expressed using the Total Obligational Authority method; that is, authorized expenditures are assumed to be made in that same year, even thought actual disbursements may occur over a period of several years. Sensitivity tests carried out in a similar study[1] showed no change in relative ranking of the alternatives considered when cash flow was substituted for TOA.

Ship Costs. Primary source of ship cost data is the Navy Program Factor Book, OPNAV 90P-02, 1966 (CONFIDENTIAL). Estimates in this book are average annual cost estimates, based on historical data for each ship class, adjusted to be valid for "Five Year Force Structure and Financial Planning" purposes. As such, they are the best available estimates for costs through 1971. Initial construction cost estimates are available for a number of ship classes. Both lead-ship and follow-on ship costs are provided. The cost of a lead-ship, the first of a new class or new design, is greater than that of subsequent ships because of such charges as those for building plans and specifications, and because of learning effects.

---

[1] Naval Warfare Analysis Group Study No. 42, Tactical Air Warfare Study II(U), Vol. II: Cost Analysis, (Arlington, Va.: Center for Naval Analyses, The Franklin Institute, 1965), (SECRET) p. 27. Cited hereafter as NAVWAG 42, Tactical Air Warfare Study II(U), (SECRET).

Ship conversion and overhaul costs represent the cost of shipyard labor, material, and overhaul expenses required to accomplish repairs during a scheduled overhaul period. In general, conversion is in addition to regular overhaul costs, and normally provides modernization and improvements in the ship's cababilities.

Annual operating costs include both direct and indirect charges against the ship. These include:

Direct Charges

1. Ship's personnel pay and allowances.
2. Non-scheduled repairs.
3. Supplies and equipage.
4. Fuel and Utilities. The average annual share of the cost of nuclear core replacement is included in this factor.
5. Maintenance Material.
6. Expendable ordnance.
7. Expendable missiles.

Indirect Charges. Charges for a pro-rata share of the facilities ashore which contribute to the operation of the ship and its crew, and which can be accurately identified.

1. Training support personnel.
2. Other support personnel.
3. Personnel general expenses.
4. Supply support.
5. Medical care.
6. Replacement training.

Salvage value of the ship at the end of the planning period was calculated as a savings equal to the fraction of years' life remaining in first-line service divided by the standard service life of the ship, multiplied by the cost of constructing an identical replacement. Since the next-best use of the CVA is employment as an anti-submarine carrier, (CVS), the opportunity cost of the CVA involves the cost of constructing the same ship for use as a CVS. No major conversion is necessary to use the ship as either CVA or CVS. For lead-ships, follow-on replacement costs are used.

Cost estimates for a hypothetical ship are given in Table 4.

Aircraft Costs. Aircraft operating costs are obtained from the Navy Program Factors Book previously mentioned. However, aircraft investment costs are highly sensitive to the total quantity purchased. The unit investment cost for a single aircraft includes the "flyaway cost" of the airframe, engines, electronics, armament, and other government furnished equipment, plus a cost factor (percent of flyaway cost) for spares, repair parts, special support equipment such as aircraft computer check-out equipment, and training equipment. This last factor includes the electronic flight simulators used extensively in ground training flight crews for their tactical mission.

Aircraft production costs also exhibit a "learning curve" effect; as more airframes are purchased, unit airframe costs tend to decline. This effect is sometimes masked by design improvements which occur after the aircraft has been placed in service. The

TABLE 4

COST ESTIMATE FOR USS HYPOTHET (CVAN-99).
(Dollars in Millions)

Construction (SCN)	$	300.000
Initial Missile Fill (PAMN)		10.000
Total - - -	$	310.000
Overhaul (O/H)	$	25.000
Annual Operating Cost (O&M)	$	27.850

Year	1968	1969	1970	1971	1972	1973	1974
Item	SCN			PAMN	O&M	O&M	O&M
Cost	300.0			10.0	27.850	27.850	27.850

Year	1975	1976	1977	1978	1979	1980	
Item	O/H	O&M	O&M	O&M	O/H	O&M	
Cost	25.0	27.850	27.850	27.850	25.0	27.850	

$$\text{Salvage} = \frac{21}{30} \times \$310.0 = \$217.0$$

TOTAL COST

RATE	PRESENT VALUE (1968)
0%	$ 337.950
10%	356.411
15%	351.708[a]

[a]Note that discounting initially reduces the effect of salvage on the total, but as the rate rises, it will reduce the entire cost stream to a smaller total than the 0% rate.

cost of improved design and newer, more effective electronics and/or armament may cause the actual unit cost to increase.

One of the assumptions made in Chapter II is that technology will be held constant for the duration of the planning period. If this is the case, then learning curves can be estimated using published sources and an estimating technique based on historical cost data of conventional fixed wing aircraft.

By use of a double-log transformation on the relationship between cost and resource requirements as a function of aircraft weight, speed, engine thrust, production rates, and production quantities, a series of curves have been estimated for unit investment costs as a function of total quantity purchased.[1] The curves developed in the reference cited were used for the analysis with two additions, A-4 and the F-8/RF-8. Since the latter two aircraft have been in the inventory for a number of years, the cost of the current modernization program was charged as initial investment cost. The aircraft is considered to have a full first-line service life remaining on completion of the rework.[2]

Cost estimates using the learning curve were obtained as follows: the Air Wing utilization and planned replacement schedule provided the quantity required for any specific purchase. One-half this amount was added to the total number of that type aircraft

---

[1]NAVWAG 42, Tactical Air Warfare Study II(U), Vol. II: pp. B-6-B-12 (SECRET).

[2]Naval Aviation News, June 1966, p. 28; and Program Change Proposal, "Modification of F-8 B/C/D/E Aircraft", 1965, approved by Secretary of Defense Memorandum of 25 April, 1966 (SECRET).

already purchased to date, obtained from the <u>Naval Aviation Summary</u>, 1 April 1966. (SECRET). The learning curve for the aircraft was then entered at that quantity on the ordinate, and the unit investment cost for that buy determined.

Annual operating costs for each aircraft were calculated from data in the <u>Navy Program Factors Book</u>, applying average annual flying hours to the cost per flying hour given there. Direct and indirect charges closely parallel those for ship operating costs.

A time-stream of cost-calculations for a hypothetical aircraft, the A-8, is given in Table 5.

The cost estimate for the basic plan is computed by adding the estimate for each ship and aircraft type included in the force structure determined.

Cost estimates for Alternatives 1 and 2 are computed by summing the marginal cost differences between the basic plan and the alternative for each year. It is immediately clear that the three alternatives do not have equal costs, since each force structure was set at its optimal level independently of the other two alternatives.

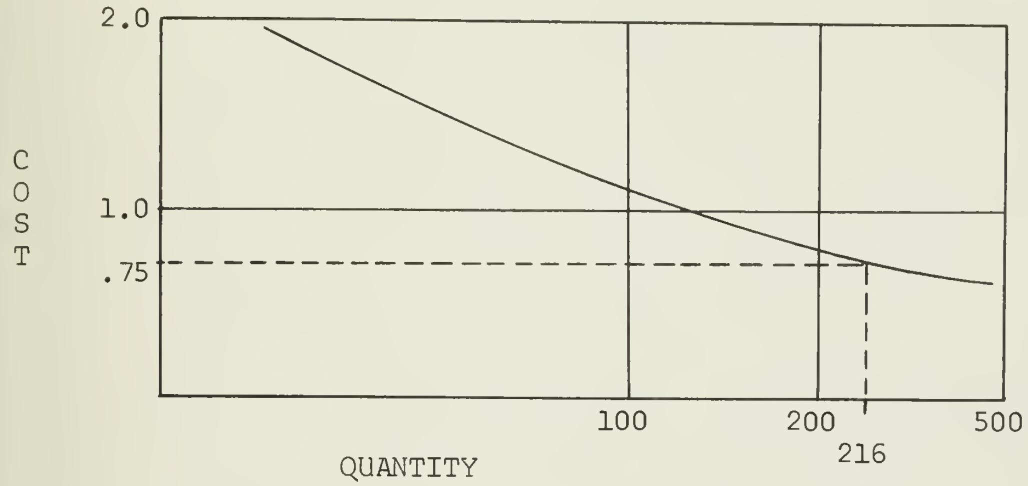
FORCE STRUCTURE

The carrier force structures to be employed are listed in Table 3. Note that a total of six different ship classes are included in the analysis.

Since the ships have comparable deck space, the air wing for the CVAN-2E-class will be the same as that used on the ENTERPRISE, CVAN-65. This will result in five different classes of carriers, with different dimensions, and therefore different aircraft capacities.

TABLE 5

COST ESTIMATE FOR A-8 AIRCRAFT
(Dollars in Millions)



Initial Buy (From Table 6)			432
÷ 2			216
+ 0 (First Purchase)		=	216
Investment Cost	$.75 X 216	=	$162.0

Annual Operating Cost (Including Overhaul) $ .80 per aircraft

Operating Cost	$.80 X 288	=	$230.4

Year	1973	1974	1975	1976	1977	1978	1979	1980
Item	INV	O&M	O&M	O&M	O&M	O&M	O&M	O&M
Cost	162.0	230.4	230.4	230.4	230.4	230.4	230.4	230.4

SALVAGE = 0 (Airframe seven years old in 1980)

TOTAL COST

RATE	PRESENT VALUE (1968)
0%	$ 1,774.800
10%	797.063
15%	557.116

The actual air wing capacity of any specific ship depends on the available deck space (including hangar deck) for parking, and on aircraft dimensions. It is quite clear that enough space must be retained on the flight deck to allow launching and recovery of aircraft. Normally the aircraft are moved aft during launch, and occupy the landing area space. After the launch is complete, remaining aircraft in the landing area must be moved forward, or outside the designated landing area (bounded by a "foul line" along its edges) before recovery of aircraft can be started. This delay caused by moving aircraft back and forth contributes to the "cycle time" of the ship, or the time between successive launches of groups of aircraft. The time for refueling and rearming returned aircraft is in addition to this "re-spot" time.

Available parking space aboard any carrier can be conveniently expressed in terms of a unit quantity of space. A convenient unit is the area (in square feet) covered by a single A-4 aircraft. The area covered by other carrier aircraft may then be expressed as the ratio of:

$$\frac{\text{Area covered by airplane X (wings folded)}}{\text{Area covered by one A-4}}.$$

Using a table of deck spotting factors for the various types of aircraft together with the available parking space on a carrier expressed in the same units, a planned load of aircraft can be constructed for that ship. For example, assume that a given carrier has room for 150 A-4 aircraft, allowing the minimum space for launch and recovery. Since the peacetime deck load is somewhat less

because the air wings are somewhat smaller, assume that all carriers are loaded to 2/3 capacity. With a hypothetical set of aircraft, a auitable air wing would consist of the following:

Carrier Air Wing Composition

	Full Load		2/3 Load
Carrier X	150		100
A/C	No. X Spot Factor	=	Total deck spot
F-13	12 x 1.8	=	21.6
A-4	28 x 1.0	=	28.0
A-8	14 x 1.3	=	18.2
RF-13	5 x 1.8	=	9.0
E-3	5 x 2.6	=	13.0
H-1	6 x .9	=	5.4
C-2	1 X 2.5	=	2.5
Total			97.7

As new aircraft are introduced into the fleet, with different spot factors, the air wing composition will change. Since the newer aircraft generally display increased effectiveness, the ship and its air wing will display a different level of effectiveness. An increase or decrease in effectiveness could be attained, depending on the changes of spot factors and effectiveness relative to each other.

Current objective plans have been used to determine air wing compositions for the 1968-1980 period.[1] Only aircraft listed in

[1]Chief of Naval Operations memorandum 00214P05, Navy Objective CVA Air Wing (U), 10 June 1966 (SECRET).

Table 2 were used, keeping the deck spot percentage essentially at the same value for each carrier class.

The total number of aircraft purchased is greater than the number required to equip each air wing. Allowances must be made for training crews, overhaul, and aircraft accidentally destroyed. The function used is:

$$N_T = N_{CVW} + N_{RCVW} + N_{PPL} + N_A$$

N_T = Total Aircraft purchased

N_{CVW} = Air Wing aircraft

N_{RCVW} = Refresher air wing aircraft

N_{PPL} = Aircraft in overhaul or repair (pipeline)

N_A = Attrition allowance.

The allownace for refresher air wings is a percentage factor of the attack air wing aircraft. Pipeline aircraft are a percentage of the sum of all operating aircraft. Finally, allowance for attrition is a function of the total number of aircraft flying, the number of hours flown annually, and the planned service life of the aircraft.

Planned flying hours for each type of aircraft are listed in the Navy Program Factors Book, OPNAV 90P-02, 1966 (CONFIDENTIAL). A variation is observed from year to year in the number of hours planned. It appears to be a function of the expected appropriations level. In order to simplify computation, representative average figures have been selected for each type of aircraft.

Attrition may be derived from the U. S. Naval Aviation Safety

Center publication U.S. Navy Aircraft Accident Statistics(U), Fiscal years 1955-1964 (CONFIDENTIAL). The attrition rate per 100,000 flying hours has exhibited a declining value for each type of aircraft as the total operating experience of the fleet with the type accumulates. An example for a hypothetical aircraft, the A-8, would be as follows:

A-8 Attrition Rate (per 100,000 hours)

Model Year	1	2	3	4	5	6	7	8	9	10
Attrition	35	31.3	26.1	20.4	12.2	8.7	5.5	4.7	4.7	4.7

The service life of a first-line aircraft varies according to its effectiveness, and as a function of technology, since new developments lead to design of replacement aircraft when significant breakthroughs occur. The A-1 is still operational, although it was designed at the end of World War II. The E-1 was first delivered in 1958; its replacement, the E-2, arrived in 1964. A useful service life of seven years has been selected for a first-line aircraft. It represents the statistical mean of first-line airframe ages at the time of their transfer to the training command or reserve forces, over the period since World War II.[1]

With the factors available, total investment in each aircraft can be calculated. Assume, for example, that the A-8 (a hypothetical aircraft) has been planned for introduction in 1974, as outlined in the discussion thus far. Each Carrier Air Wing is to

[1] NAVWAG 42, Tactical Air Warfare Study II(U), Vol. II; p. B-7 (SECRET).

have one squadron of 14 aircraft. Assume an allowance of 25% for Refresher Wings, a pipeline factor of 10%, and annual flying rate of 360 hours/year. The calculations are shown in Table 4.

In calculating aircraft buys for the three alternatives, the existing air wings in 1968 were used as a starting point. Using estimated planning factors and planned introduction schedules for new aircraft, the total buy was calculated for the 1968-1980 period. The resulting time-phased purchase schedule and force structure was then used in the cost analysis described below.

TABLE 6

A-8 INVESTMENT

15 Carriers x 14 aircraft/carrier	=	210 aircraft
25% refresher x 210	=	52
		262
10% pipeline	=	26
		288

$$\text{Attrition} = \frac{\text{288 aircraft x 360 hours/year x attrition rate}}{100{,}000}$$

Year	Model Year	Attrition Rate	Attrition
1974	1	35	36.288
1975	2	31.3	32.452
1976	3	26.1	27.060
1977	4	20.4	21.151
1978	5	12.2	12.649
1979	6	8.7	9.020
1980	7	5.5	5.702
			144.322

Total buy = 288 + 144 = 432 aircraft.

Escorts, in the form of Frigates (DLG and DLGN), and two types of support ships, Ammunition ships (AE) and Oilers (AOR), are assumed to be available as needed. Although these ships were not directly included in the force alternatives, the cost of constructing and operating one of each type was included in the cost estimation for use in the effectiveness calculations and sensitivity tests.

FORCE ADJUSTMENT

The problem of marginal effectiveness in equal-cost cases was outlined in Chapter II. In order to set each alternative equal to the other in costs, adjustments are made in the aircraft inventory only. The time-phasing of the ships is considered fixed, since it forms a fundamental part of the hypothesis. Clearly the deck load of helicopters or transports could be altered, but this would have no effect on the force's selected measure of effectiveness. Therefore adjustments will be made primarily in the attack aircraft load, by buying more or less A-7 aircraft for use on the AMERICA-class and CVAN-2E-class carriers. A deck load of 100% capacity will not be exceeded in these adjustments.

It is important that adjustments to the force structure alter the effectiveness which is to be measured. Clearly a Volkswagen and a Cadillac do not cost the same. If the measure of effectiveness is the ability to carry the driver and two passengers from one point to another, no amount of chrome-plated fixtures and platinum hub-caps added to the Volkswagen to set its cost at the Cadillac level will alter the MOE by any significant amount.

In amy event, it is fortunate that this analysis is only comparing Ford with Chevrolet and Pontiac.

Note that the marginal effectiveness sensitivity discussed in Chapter II demands that all three alternatives be set equal at each of the three levels determined by optimum force structures. At each different discount rate, the cost difference will vary; thus a total of 27 possible force structures will be estimated.

SENSITIVITY ANALYSIS

Conventional-powered escort ships have already been assumed available for each carrier in the force. To test sensitivity in this case, comparable nuclear escorts (4 DLGN) will be assigned to each nuclear carrier in the alternatives. The additional cost will then be compensated for by adjustments in the aircraft inventory.

A number of sensitivity tests have been proposed besides the equal-cost, marginal-effectiveness test and the discount rate. Length of the planning period is tested by extending the forces through 1990, applying the same adjustment technique to set them at equal cost.

In the escort case, no effort will be made to evaluate the change in effectiveness gained by having an all-nuclear force. The increase in mobility without the need for underway replenishment is the primary factor here. However, no attempt will be made to charge conventionally-powered escorts with replenishment requirements either. The assumption is that conventional-power escorts will be fueled by the CVA which they escort. This is the

normal procedure today, since escorts must be refueled every few days when accompanying a carrier during flight operations. A portion of the fuel oil on the carrier is reserved for this purpose.

A calculation of support ship requirements, and therefore charges, is a function of the effectiveness scenario selected. Discussion and examples are in Chapter IV.

Once a number of equal-cost alternatives have been constructed, they must be operated in a hypothetical wartime scenario in order to measure their relative effectiveness. The choice of that scenario and its importance to the results obtained is fully discussed in the following chapter.

CHAPTER IV

EFFECTIVENESS

The critical importance of the measure of effectiveness to the results of the analysis has been discussed several times thus far. The MOE must be relevant to the assigned mission, and it must be measurable. This is the only way in which a relative ranking can be established between the several alternatives specified.

Effectiveness can be defined as the ability of the force to carry out its assigned mission. The most direct method of measurement would be to actually exercise such a force in a real contingency. This is impossible for a number of practical reasons, over and above the fact that the forces themselves will not exist for several years.

A highly useful abstraction from the real world is the use of a modern high-speed computer to simulate conflicts. With a carefully designed program, forces can be brought to bear against the enemy, and their resulting effectiveness measured. Attrition due to enemy action can be included in an analysis of this type, thus extending the value of the MOE.

In the absence of real-world forces and computer simulations, a simpler MOE must be accepted. One of the most important missions of the Attack Carrier Striking Force is the provision of tactical air support in conventional warfare situations where land-based

support is inadequate or unable to be brought to bear. The ready availability of carrier forces has been demonstrated again and again, both in situations where combat resulted, and where it did not; Korea, Quemoy, Lebanon, Cuba, the Dominican Republic, and Viet Nam. The capability to station a completely self-contained air base in an area where potential conflict exists without the accompanying diplomatic complications attendant upon airfield use agreements, port unloading facilities, the American presence in the country in an atmosphere of tension, etc. is a recommendation for its purchase even if other methods of performing the same military mission were sufficient for this country's world-wide commitments.

In a situation such as this, the theater commander is vitally interested in the forces at his disposal. In particular, his ability to meet a threat can be evaluated by measuring the total weapon delivery of the force available to the commander throughout the course of a postulated conflict. This capability has been selected as the primary MOE for this analysis.

While the absolute level of effectiveness thus measured might be questioned because of the numerous caveats presented in the analysis, the relative level of the alternatives remains a valid measure of their order of preference. The ranking is among alternative mixes of the same type force; thus many of the problems inherent in comparing different types of forces in performing the same mission simply do not exist.

The MOE is a variable, subject to a number of factors. The total delivery depends on how fast the carriers can respond to the

crisis (their mobility); the delivery rate of the carrier air wing, which is itself a function of the mission and distance to be flown; the carrier time-on-line between replenishments; ability to transfer to a new location on short notice, should the situation change unexpectedly; and vulnerability of the force to enemy action. All of these factors will be addressed except the last. No attrition other than normal peacetime attrition will be assumed, and replacement aircraft will be provided from non-engaged air wings or the pipeline whenever a loss occurs. Adequate analysis of the question of vulnerability would be the subject of a complete study by itself.

In constructing a scenario to exercise the forces under the conditions outlined, several steps are required:

1. The particular conflict must be specified in terms of location, magnitude, warning time, and duration.

2. Theater forces available at the start of the conflict must be determined.

3. An augmentation schedule must be constructed for the additional forces to be committed.

4. The forces must be "played" to evaluate the MOE.

Sensitivity to the factors of mobility and duration will be evaluated by using two separate scenarios with different characteristics. The two will differ in terms of:

1. Distance from theater and augmenting force locations.

2. Distance between underway replenishment area and resupply base.

3. Duration of the conflict.

Because the air wing inventory changes over time as new aircraft are introduced, effectiveness will vary. In order to test the sensitivity, the alternative forces will be exercised and evaluated in two different years. One will be in the transition period, 1973, when the force structure is most different in terms of carriers available. The second will be 1975, when aircraft model replacement will be considered complete for each class of carrier.

COMMON FACTORS

In all scenarios, certain factors are required. These will be held constant from situation to situation.

Attrition has already been mentioned. Peacetime attrition was assumed, with replacement by flying new aircraft to the ship as needed. Loss of the usefulness of that aircraft until replacement is allowed for in the sortie rate.

Air defense will be assumed constant for each force. The capability of different aircraft will be taken into consideration; i.e., one F-111B will be considered equivalent to two F-4 aircraft for air defense. Although both the F-111B and the F-4 are capable of carrying out attack missions, it is assumed that the full fighter complement of these two aircraft is engaged in air defense functions.

The sortie rate for an aircraft is a function of the following factors:

1. base facilities, including refuel/rearm capability
2. aircraft characteristics

3. pilots
4. weather and geography
5. assigned missions
6. operational factors.

Base facilities affect how long it takes to prepare an aircraft for its next mission, and include the possible repair of damaged or failed equipments. Aircraft characteristics include ease of loading ordnance, and time to execute a mission, which is a function of speed and distance to be covered. Pilots, weather and geography determine the number of opportunities to fly in a given day; pilot fatigue limits the number of missions each can fly in a day, while weather and geography affect how long it takes to fly each mission. An aircraft which needs daylight and clear weather to find and attack its target will have fewer opportunities to fly than an all-weather aircraft capable of delivering weapons at any time. The specific target to be attacked may itself determine the opportunity; troops in combat are too mobile and present little or no radar reflection for the all-weather aircraft, and thus may be a poor target for night-time or overcast-day attacks.

The assigned mission, in terms of target type and distance from base determine mission time, and thus opportunities to sortie. Finally, operational factors, including aborted missions, peacetime accidents, etc. will reduce the sortie rate capability.

Sortie rates for attack aircraft in the inventory have been calculated with the aid of a computer program for another study.[1]

---

[1]NAVWAG 42 Tactical Air Warfare Study II (U), Vol. III, Effectiveness Analysis, Appendix G (SECRET).

These rates will be used in this analysis.

These sortie rates are calculated for carriers loaded with an optimum air wing, which is less than 100% of parking capacity. As the number of aircraft operating from the carrier changes from the optimum, the sortie rate will tend to vary. No statistical study has been carried out to date on this factor; however it would be less than realistic to assume it does not exist. Based on the author's experiences with four different carriers, the following factors are assumed:

Deck spot factor	Sortie rate
≥ .95	.90xS
.90 to .949	.95xS
.80 to .899	Calculated rate, S
≤ .799	1.05xS

The change in sortie rate occurs because the ship has a limited number of bomb elevators to bring up the weapons for loading, because there is a relatively fixed number of men available to provide the weapons and load them, and because the time required to re-spot the deck for launches and recoveries increases when more aircraft must be moved. The final factor considered is the fact that increased presure on the crew as a result of an increased tempo of operations tends to lead to an increased number of flight-deck collisions between aircraft and between equipment and aircraft. The result is that the over-all sortie rate of the ship is reduced for increased deck loads.

Targeting will affect the total weapon delivery capability, since the mission and distance govern the ordnance load which can be carried. To standardize this factor for the study, the following targeting factor will be assumed:

Mission	Distance	Percent of Total Sorties
Close Air Support	300 Mi.	60
Air Superiority and Interdiction	500 Mi.	40

Ordnance capability of the assigned aircraft as a function of mission and distance have been calculated and plotted as a set of curves in Appendix A. Calculations were based on data in the performance handbook for each type, for standardized missions. Ordnance payload capability was based on the following mission rules:

1. Reserve fuel to be 5 percent of initial total fuel plus fuel for 20 minutes' loiter at sea level at the end of the mission.

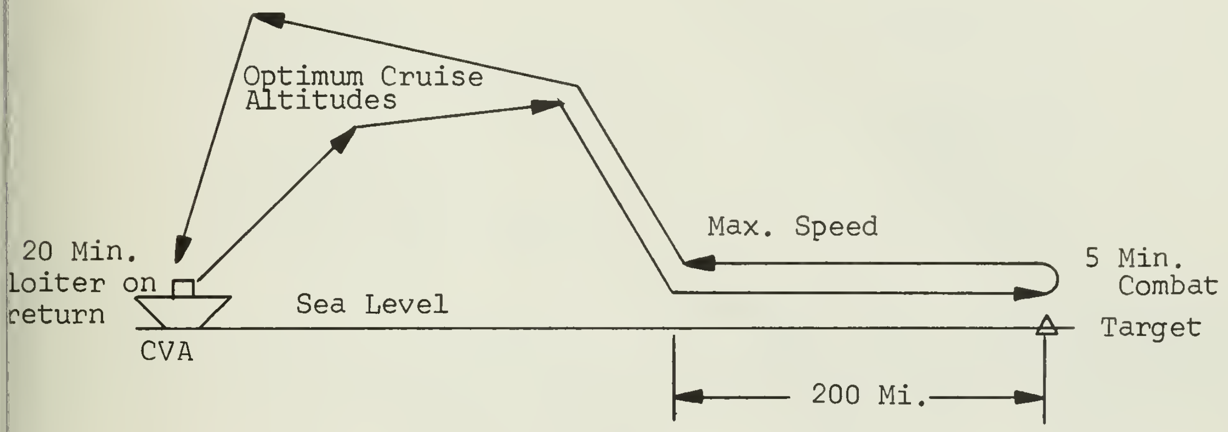
2. Combat fuel is weight of fuel required for operation at military rated thrust throttle setting for 5 minutes.

3. External pylons and fuel tanks will be retained at all times.

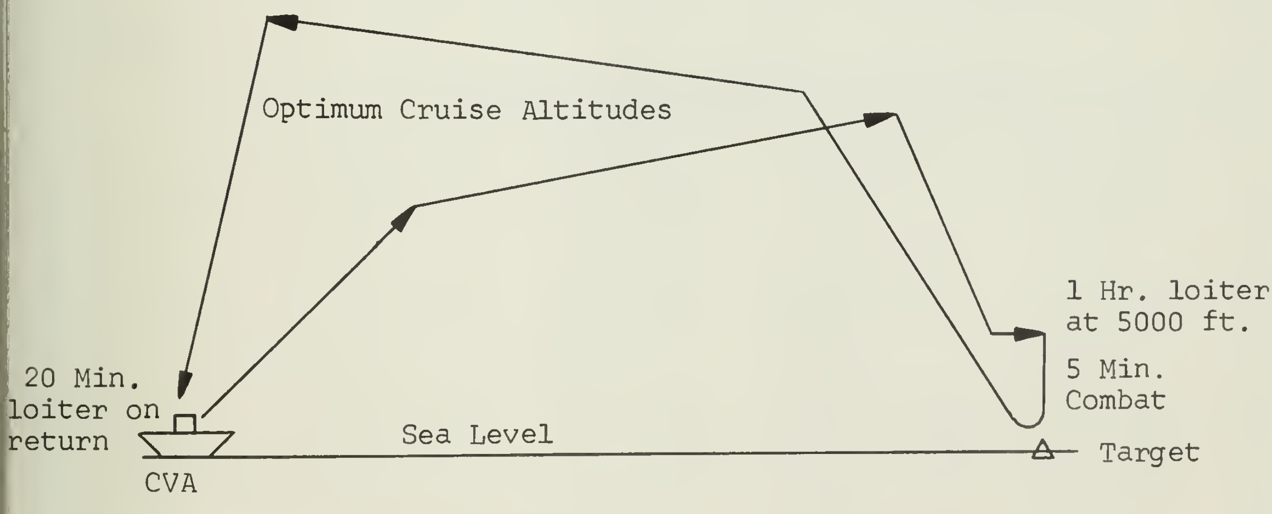
Two standard profiles were used, as displayed in Figure 3. Fuel and ordnance were selected to represent typical loads used for each type of mission, since the variety of attack weapons and external fuel tank capabilities prohibits complete calculation of all possible alternatives. The resulting curves of aircraft capability could be used in other postulated scenarios to further extend the effectiveness testing, if time were available. Sample calculations and curves are shown in Table 7 and Figure 4.

FIGURE 3

MISSION PROFILES



ATTACK



CLOSE AIR SUPPORT

TABLE 7

SAMPLE MISSION PROFILE CALCULATIONS
Attack Mission

A-8

Basic Weight	10,000 lbs.
Crew, tanks, pylons, oil.	500 lbs.
Operating weight	10,500 lbs.
Maximum catapult weight	30,000 lbs.

Mission	Ordnance	Fuel, lbs.	Takeoff Weight
1	4 - 500 lbs Snakeye	17,000	29,500
2	3 - 1000 lbs. lo-drag	15,000	28,500
3	2 Bullpup Missiles	13,000	28,500
4	18 - 100 lbs. fragment.	17,000	29,300

Phase/ Mission	1		2		3		4	
	Fuel	Distance	Fuel	Distance	Fuel	Distance	Fuel	Distance
Climb	2000	90	1700	75	2400	105	2200	100
Cruise out	3000	260	2000	190	750	45	2850	245
Descent	100	70	100	70	100	70	100	70
Run-in/out	6000	400	6000	400	6000	400	6000	400
Combat (5 min.)	1000	-	1000	-	1000	-	1000	-
Climb	850	60	850	60	850	60	850	60
Cruise in	2550	290	1950	205	600	90	2500	285
Descent/loiter	650	70	650	70	650	70	650	70
Reserve	850	-	750	-	650	-	850	-

TABLE 7 (Cont.)

(i) Mission	(Y) Ordnance	(X) Range
1	2000	620
2	3000	535
3	5000	420
4	1800	615

$\bar{X}, \bar{Y} \quad = \quad$ mean of X and Y

$x_i \quad = \quad X_i - \bar{X}$

$y_i \quad = \quad Y_i - \bar{Y}$

$\bar{X} \quad = \quad 547.5$

$\bar{Y} \quad = \quad 2950$

i	x	y	$x_i\ y_i$	x_i^2	y_i^2
1	72.5	-950	-68,875.0	5,256.25	902,500
2	-12.5	50	-625.0	156.25	2,500
3	-127.5	2,050	-261,375.0	16,256.25	4,202,500
4	67.5	-1,150	-77,625.0	4,556.25	1,322,500
Σ			-408,500	26,225.0	6,430,000

$$\hat{\beta} = \frac{\Sigma x_i\ y_i}{\Sigma x_i^2} = -15.58$$

$$Y = \hat{\partial} + \hat{\beta}\ X$$

$$\hat{\partial} = \bar{Y} - \hat{\beta}\ \bar{X} = 11{,}480.050$$

$$\sigma_{\hat{\beta}}^2 = \frac{\sigma_u^2}{\Sigma\ x_i^2} \qquad \text{where } \hat{\sigma}_u^2 = \frac{\Sigma\ e_i^2}{n-2}$$

$$\text{and} \quad e_i = y_i - \hat{\beta}\ x_i$$

$$\sigma_{\hat{\partial}}^2 = \frac{\Sigma\ X_i^2}{n\ \Sigma x_i^2}\ \sigma_u^2$$

TABLE 7 (Cont.)

$$r^2 = \hat{\beta}^2 \frac{\Sigma x_i^2}{\Sigma y^2} = \frac{(\Sigma x_i y_i)^2}{\Sigma x_i^2 \ \Sigma y_i^2}$$

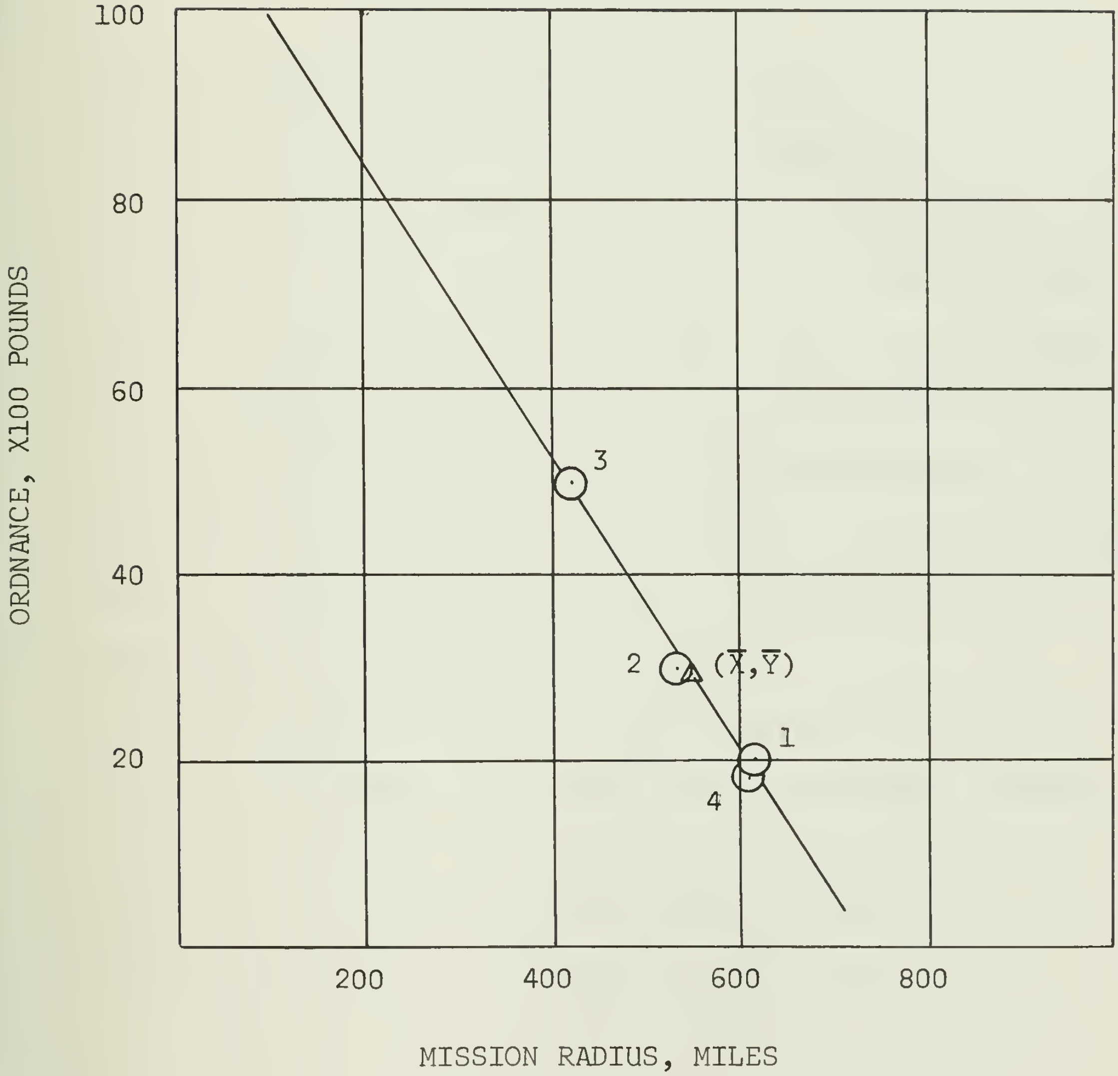
i	χ^2	e^2
1	384,400	32,238.2025
2	286,225	20,952.5625
3	176,400	4,038.6025
4	378,225	9,672.7225
Σ	1,225,250	66,902.09

$$\hat{\sigma}_u^2 = \frac{66,902.09}{2} = 33,451.045$$

$\sigma_{\hat{\beta}}^2$	$\sigma_{\hat{\partial}}^2$	r^2
1.28	390,713.85	.9895

FIGURE 4

A-8 ATTACK MISSION CAPABILITY



It should be noted that the smooth curves plotted are only approximations, since weapons come in discrete weight units. A series of performance points were calculated, and a linear regression using least-squares techniques was performed to develop the curves.

Underway replenishment requirements vary for each scenario, but the method of calculation is the same for each case. Replenishment is a function of usage rate, and therefore the carrier's capacity for storing jet fuel, black oil (NSFO), and ordnance. These last three will determine the length of time the carrier can remain on the line. Underway replenishment must be calculated to be available at the expiration of this period, in the quantity required. The distance between the underway replenishment area and the resupply port, coupled with reloading time in port, determines how often a given replenishment ship can provide supplies.

The first step is to determine time-on-line for each carrier and air wing. Ship capacities of the three items being consumed are listed for each class of carrier. Expenditure rates are then calculated with the ship operating at maximum combat effort. One simplification here is the assumption that the exact ordnance required for assigned missions is loaded aboard the carrier. The real-life frustrations experienced by the Mission Planning Board on every carrier in the fleet when the remaining ordnance is inappropriate for the assigned mission have been shared to a small degree by the writer in years past.

Expenditure rates in tons per strike day for ordnance and gallons (or tons) of jet fuel determine the number of days the carrier can remain on-line before requiring replenishment. For NSFO, the additional black oil required for transit to and from the replenishment area, plus a day's expenditure during underway replenishment must be subtracted from usable capacity.

The shortest time of the three calculated determines the number of days the carrier can remain on the line. The limitation can be caused by NSFO, or either of the other two items. The particular limitation varies among the ship classes considered. A hypothetical example is given in Table 8.

Replenishments are planned to allow maximum daylight hours for the carriers both while on-the-line and while replenishing ammunition. Transits are made during darkness after the last days' strikes have been recovered. Ammunition is replenished first, followed by jet fuel and NSFO, which can extend into darkness. Return transit is performed on completion of refueling, so that strikes may commence at first light the following day.

The calculation method used leads to fractional ship requirements for a carrier. Such fractions may be considered valid measure of requirements provided that the full capacity of the individual ships can be utilized on each trip by the other forces engaged in the operation. When expressed in terms of costs, the fractional ship approach can be understood as a method of allocating costs to marginal units. The assumption of a maximum combat effort by a number of carriers supports the argument of full utilization of capacity.

TABLE 8

HYPOTHETICAL CARRIER TIME-ON-LINE

Capacities		
NSFO	100%	72,000 bbl.
reserve	30%	24,000 bbl.
available	70%	48,000 bbl.
Jet Fuel	100%	60,000 bbl.
reserve	10%	6,000 bbl.
available	90%	54,000 bbl.
ORDNANCE	100%	10,000 tons
usable	90%	9,000 tons
Expenditure Rates		
NSFO		7,000 bbl./day
Jet Fuel		6,000 bbl./day
Ordnance		750 tons/day
Additional NSFO		
Transit to URG		2,500 bbl.
Replenish		1,500 bbl.
Strike Endurance at Maximum Rates		
NSFO		6.3 days
Jet Fuel		9.0 days
Ordnance		12.0 days

Time-on-line = 6 days

Replenishment every 7 days

The actual number of replenishment ships required to support a force in any given situation can be determined mathematically if certain factors are known or can be reasonably assumed. We have discussed the calculation of carrier time-on-line; this generates the demand; what supplies are required, how much, and how often. We must also know the characteristics of the replenishment ships; their capacities, their cycle times, and their cargo transfer rates.

The two replenishment ships we will consider are the AOR, for fuel, and the AE for ammunition. For each type, the replenishment ship cycle is calculated as follows:

TABLE 9

UNDERWAY REPLENISHMENT GROUP CYCLE TIME

Distance from URG area to resupply port	X miles
Speed of Advance (SOA)	Y knots
Transit time (one way) $\frac{X}{24Y}$ = T days	
Transit to port	T days
In port delay and loading time	L days
Transit to URG area	T days
Standby/Replenish/Consolidate Cargo	1.0 day

Total cycle time = 2T+L+1.0 days = CT + TOS (See below)

With the cycle time and ship capacities known the numbers of replenishment ships required to support each of the carriers can be calculated by formula.

In equilibrium,

Cargo delivered per day = Material expended per day

or

$$\frac{N \times Y}{CT + TOS} = \frac{X}{R}$$

$$N = \frac{X}{R} \times \frac{CT + TOS}{Y}$$

N = number of AOR or AE required

Y = transferable cargo of URG ship (expressed in tons, gallons, barrels)

CT = cycle time = time to transit each way plus time to load in port.

TOS = time on station = waiting time plus offload time

X = cargo requirement of a force during replenishment (expressed in tons, gallons, barrels)

R = frequency of combatants' replenishment (in days)

For example, using a hypothetical CVA and AOR:

Y = 180,000 barrels

CT = 8 days

TOS = 1 day

CVA POL = X = 60,000 barrels (POL = petroleum products)

R = 7 days

$$N_{AOR} = \frac{60{,}000 \text{ barrels}}{7 \text{ days}} \times \frac{8 \text{ days} + 1 \text{ day}}{180{,}000 \text{ barrels}}$$

$$= \frac{60{,}000}{7} \times \frac{9}{180{,}000} = \frac{3}{7} = .43 \text{ AOR}$$

Replenishment charges will be calculated for each carrier type as a secondary MOE. No attempt will be made to incorporate these

charges into the equal-cost structures by compensating adjustments in attack aircraft. The implications of replenishment charges are discussed in Chapter V.

EFFECTIVENESS SCENARIOS

Any scenario selected for study is obviously arbitrary. A complete evaluation of the alternatives would require an almost infinite number of different ones. Because of the time constraints on a single analyst, just two have been selected. They differ in distance from supporting forces and in duration, in order to test the sensitivity of the MOE to response time of the carrier from its starting point and its capability to remain on the firing line once it arrives. The framework outlined could be extended to additional scenarios with little additional effort, if further testing appeared necessary.

A non-nuclear confrontation is not difficult to envision; six of them were mentioned at the beginning of the chapter. It is important that the scenario postulated serve as an appropriate vehicle to exercise the alternative forces and allow their effectiveness to be measured.

In both cases, the situation consists of a no-warning surprise attack. The apparent goal of opposing forces is rapid consolidation of limited gains followed by a negotiated cease-fire. The assumption is that the situation is critical enough to warrant employment of as much of our tactical air power as possible while maintaining pre-hostilities posture elsewhere. It is further assumed that conditions do not warrant acceleration of overhaul schedules to bring other carriers into the conflict, and that contributions by the Marine and Air Force tactical air wings is constant.

It was pointed out that the primary MOE would be the total tonnage of ordnance available for delivery during the conflict; this implies that sufficient targets exist to warrant such delivery.

Two areas which immediately come to mind for scenarios are Europe and Southeast Asia, the first because of our National interest in the Continent and its defense, and the second because our forces are currently engaged there. It is felt that more can be contributed by selecting two different areas than by re-examining those which have been thoroughly covered by other analysts.

For each scenario, we must specify the location and duration. The theater forces available are a function of current peacetime deployment schedules. Force augmentation is calculated considering overhaul schedules and the requirement to maintain pre-hostilities posture elsewhere in the world.

The force deployment schedule and time-on-line data for each type of carrier will determine how many days each ship will be employed in the conflict. Applying delivery capability on the schedule presented earlier will result in calculation of total tonnage delivery during the conflict.

An analysis of support-ship requirements can be made separately. It is a function of the location of resupply ports and their distance from the underway replenishment area, as well as the demands imposed by the carriers.

Scenario A

Tension has been mounting in the Middle East, centering in Tehran. Without warning, an overthrow of the government is

TABLE 10

PEACETIME CARRIER DEPLOYMENT

Scenario A

		Pacific		Atlantic	
		7th Flt	1st Flt	6th Flt	2nd Flt
Basic Plan	1973	1 Hancock 1 Forrestal 1 America	1 Hancock 1 Midway 1 CVAN-2E 1 America 2 Forrestal	1 Enterprise 1 America	2 Midway 1 Forrestal 1 AMERICA
	1975	1 Hancock 1 Forrestal 1 America	1 Midway 2 Forrestal 2 America 1 CVAN-2E	1 Enterprise 1 America	2 Midway 1 Forrestal 1 CVAN-2E
Alternative No. 1	1973	2 America 1 Forrestal	1 Hancock 1 Midway 1 America 2 Forrestal 1 CVAN-2E	1 Enterprise 1 America	2 Midway 1 Forrestal 1 America
	1975	2 America 1 Forrestal	1 Midway 2 America 2 Forrestal 1 CVAN-2E	1 Enterprise 1 America	2 Midway 1 Forrestal 1 America
Alternative No. 2	1973	1 CVAN-2E 1 Forrestal 1 America	1 Hancock 1 Midway 2 Forrestal 1 America 1 CVAN-2E	1 Enterprise 1 America	2 Midway 1 Forrestal 1 America
	1975	1 America 1 Forrestal 1 CVAN-2E	1 Midway 2 Forrestal 2 America 1 CVAN-2E	1 Enterprise 1 America	2 Midway 1 Forrestal 1 CVAN-2E

Fleet Locations:

1st - Eastern U.S. Coast
2nd - Western U.S. Coast
6th - Mediterranean Sea
7th - Western Pacific

attempted, supported by revolutionary forces from all neighboring countries. Iran appeals to the United States for help in putting down the opposing forces, who have obtained considerable military hardware, including aircraft.

The attack carrier striking force is deployed as outlined in Table 10. The two Mediterranean carriers in the 6th Fleet are ordered to deploy to the waters East of Cyprus to conduct close air support and interdiction operations. At the same time, one carrier is ordered to make ready and deploy from Norfolk to operate East of Cyprus, and one carrier from the 7th Fleet is ordered from Manila to operate in the Gulf of Oman, South of Iran.

Because of the political situation throughout the Middle East, resupply of the forces at sea will be provided by ships operating from Italy in the Mediterranean and Karachi in the Indian Ocean area. Figures 5 and 6 display the geographic relationships involved.

The Commander, Sixth Fleet asks his staff to provide him with an estimate of the maximum ordnance tonnage which can be delivered from the start of operations to D+29, a thirty-day period. Support ship requirements must also be calculated for carriers operating on the line.

The ENTERPRISE is operating in the Eastern Mediterranean, and can commence operations on D-day. The AMERICA-class carrier in the Western Mediterranean arrives in time to commence operations on D+1. Arrival time of augmenting carriers is a function of readiness for sea and of transit speed capability. Conventional-

FIGURE 5

SCENARIO A - CARRIER OPERATING AREAS
vis-à-vis THE CONFLICT AREA

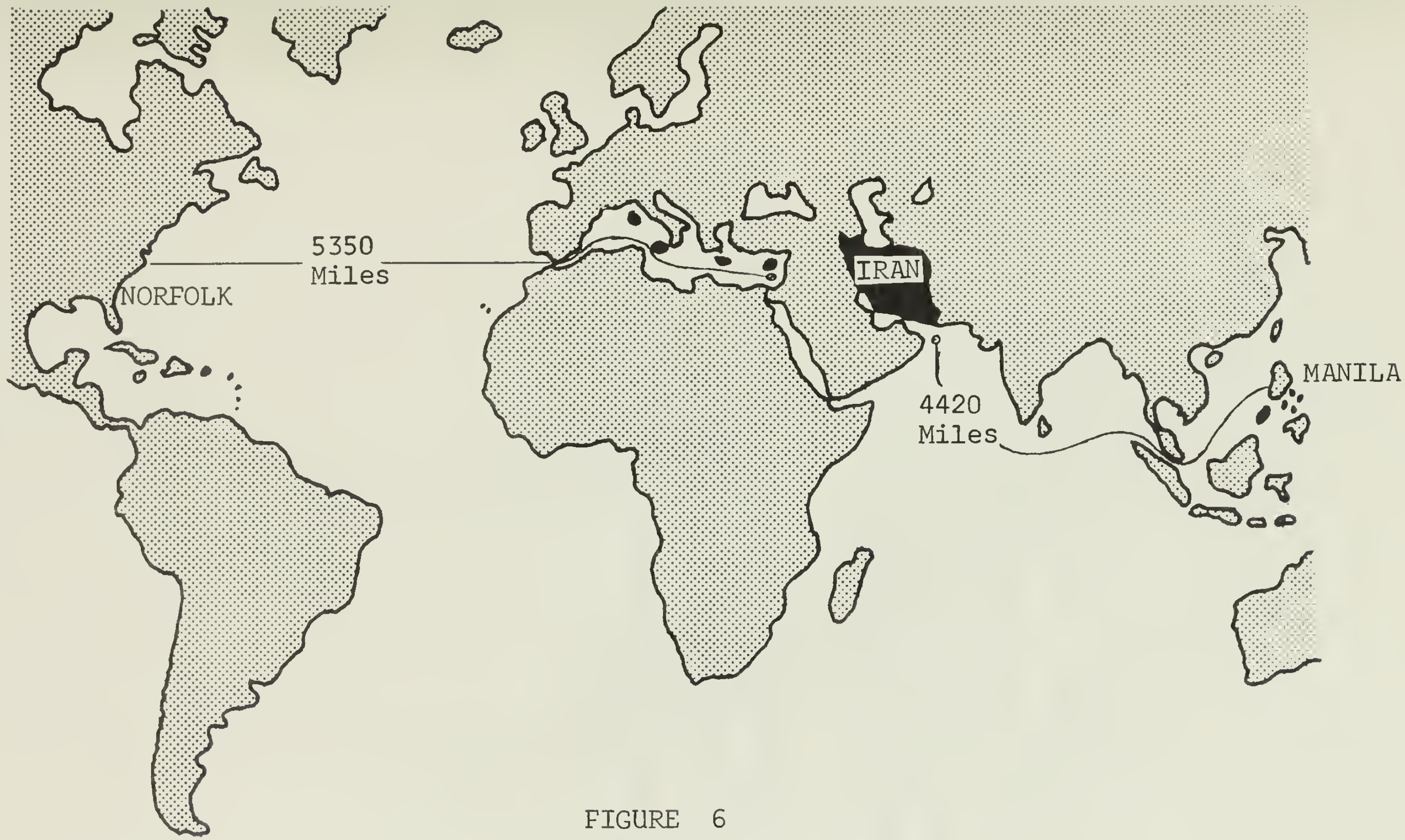


FIGURE 6

SCENARIO A - CARRIER AUGMENTATION

ROUTES AND DISTANCES TO OPERATING AREAS

powered ships are assumed to transit to the operating area at 27 knots, making good a 25-knot Speed of Advance or SOA. The CVAN can transit at 30 knots, making good a 28-knot SOA. The difference is due entirely to best speed for fuel economy considerations, not seaworthiness. Augmentation for each alternative is listed in Table 11.

Time-on-line for each class of carrier has been discussed previously. A hypothetical example was given. Using the augmentation schedule and time-on-line data, total days on-line for each carrier can be calculated. Weapon delivery rates can then be applied for the conditions outlined, and the total ordnance delivery capability determined.

Results of the calculations using the hypothetical data previously derived are shown in Table 12. A calculation of this form will be made for each alternative force structure, for each of the years 1973 and 1975. Results are in Appendix C.

TABLE 11

CARRIER AUGMENTATION SCHEDULE

Scenario A

1973

Alternative	Ship Class & Arrival			
	Med.	W. Med.	Norfolk	Manila
Basic	Enterprise D + 0	America D + 1	America D + 10	Hancock D + 8
Alt. 1	Enterprise D + 0	America D + 1	America D + 10	America D + 8
Alt. 2	Enterprise D + 0	America D + 1	America D + 10	CVAN-2E D + 7

1975

Basic	Enterprise D + 0	America D + 1	CVAN-2E D + 9	Hancock D + 8
Alt. 1	Enterprise D + 0	America D + 1	America D + 10	America D + 8
Alt. 2	Enterprise D + 0	America D + 1	CVAN-2E D + 9	CVAN-2E D + 7

TABLE 12

SAMPLE EFFECTIVENESS IN SCENARIO A

BASIC PLAN -- 1973

Carrier Class	Enterprise	America	America	Hancock
Arrival	D + 0	D + 1	D + 10[a]	D + 7[b]
Time-on-line[c]	6 days	6 days	6 days	6 days
Strike Days	26	25	18	20
Ordnance Rate	750 tons/day	650 tons/day	650 tons/day	550 tons/day
Total Ordnance	19,500	16,250	11,700	11,000

Total Ordnance Capability of the Force = 58,450 Tons.

Notes: [a]1 days' loading plus 8.9 days' transit with top-off of fuel tanks on arrival from Norfolk.

[b]Ship deploys on D-day from Manila

[c]Assumed the same for all ships for this hypothetical example.

Scenario B

For some time the Caribbean Sea had been percolating with unrest. Intelligence estimates had forecast possible Cuban interference in the affairs of almost every island and country surrounding the sea. The sudden military overthrow of the government in Venezuela did not come as a surprise, although the rapid reinforcement of the insurrectionists with Cuban-supplied Soviet war materials, including bombers and fighters, was an unexpected development. The announced aim of the rebels' plan to "Crush reactionary Imperialism throughout our hemisphere!!" caused the OAS to declare that the putting down of the rebellion was vital to preservation of freedom in the Caribbean.

Events moved rapidly, and on D+1 the first attack carrier arrived on the scene from Puerto Rico to provide support for the Marine Division landing from the Amphibious forces who had been kept at sea for just such an emergency. The Carrier Division Commander evaluated the threat, and requested Commander Second Fleet to provide two more carriers for the operation. The lack of air bases ashore for air support operations prompted this request.

The Division Commander expects the entire operation to last 14 more days, or until D+15. He asks his staff to provide him with estimates of the maximum ordnance tonnage which can be delivered by the force, and the support ship requirements. Resupply will be provided through Roosevelt Roads in Puerto Rico.

Figure 7 displays the geographic relationships. Table 13 lists the augmentation schedules for the alternatives. Table 14 is a

FIGURE 7

SCENARIO B

CARRIER OPERATING AREAS

vis-à-vis THE CONFLICT AREA

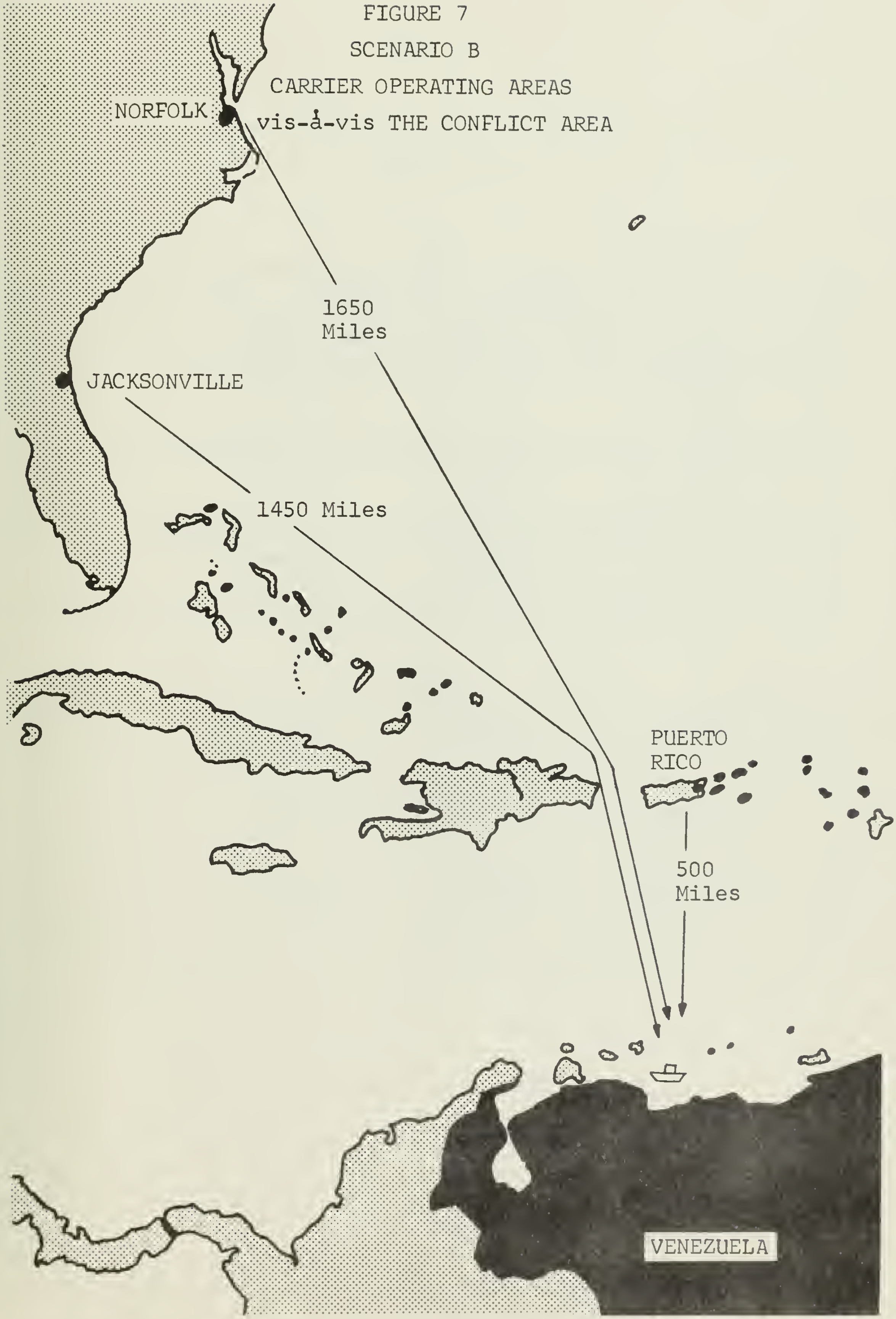


TABLE 13

CARRIER AUGMENTATION SCHEDULE

Scenario B

1973

Alternative	Ship Class & Arrival		
	Puerto Rico	Jacksonville	Norfolk
Basic	America D + 1	Hancock D + 4	CVAN-2E D + 5
Alt. 1	America D + 1	America D + 4	CVAN-2E D + 5
Alt. 2	America D + 1	CVAN-2E D + 4	CVAN-2E D + 5

1975

Basic	CVAN-2E D + 1	Hancock D + 4	CVAN-2E D + 5
Alt. 1	CVAN-2E D + 1	America D + 4	America D + 5
Alt. 2	CVAN-2E D + 1	CVAN-2E D + 4	CVAN-2E D + 5

calculation similar to that for Scenario A, for a hypothetical case.

TABLE 14

SAMPLE EFFECTIVENESS IN SCENARIO B

ALTERNATIVE I -- 1975

Carrier Class	Enterprise	America	America
Arrival	D + 1	D + 4[a]	D + 5[b]
Time-on-line	6 days	6 days	6 days
Strike Days	13	11	10
Ordnance Rate	750 tons/day	650 tons/day	650 tons/day
Total Ordnance	9,750	7,150	6,500

Total Ordnance Capability of the Force = 23,400 Tons.

Notes: [a] From Jacksonville, Florida

[b] From Norfolk

Support ship requirements for each scenario are computed as described at the beginning of the chapter. Carrier time-on-line will be the same for a carrier with the same air wing composition in any scenario; the main difference in calculation of ship requirements is the distance between the Resupply base and the Underway Replenishment area. Allowing a 250-mile retirement from the operating area for replenishment results in the following transit distances for supply ships:

Italy	750 miles
Karachi	150 miles
Roosevelt Roads	250 miles

The result of increasing distance is to incrase N when the formula is applied. This is a logical result, since a longer transit means more supply ships must be enroute between base and URG area to fill the "pipeline" being used.

Support ship "requirements" are tabulated as the fractional ship charges for each class, in Appendix D. The implications of this requirement are discussed in Chapter V, where the unclassified portion of the test results is displayed and evaluated.

CHAPTER V

TEST RESULTS

The production manager of the Edge-Ring Division may be a bit surprised when his analysts report the results of their study. That is, he will be if he expects the "answer" to his equipment replacement schedule. It was pointed out in Chapter II that cost-benefit, or cost-effectiveness analysis does <u>not</u> make the decision. It presents the necessary information regarding the proposed alternatives in such a way that the decision-maker has a clear picture of the results of his decision, no matter which alternative is chosen. The results of the analysis of the proposed alternative methods of replacing the HANCOCK-class carriers are designed to do just that for the Navy Department. This chapter contains an unclassified summary, while Appendices B, C, and D contain the actual results obtained.

The three alternatives were first set up at their optimal level, using proposed Carrier Air Wing complements for each class of carrier. The result, in terms of cost, was not surprising. Alternative One was less expensive, since conventional-power was substituted for nuclear power in the last two carriers. The air wings are slightly smaller, although the percentage of deck-spot was held essentially constant for each ship class.

Alternative Two was the most expensive, since the early purchase of A-7 and F-111 aircraft for the replacement carriers meant

they would be operated for one or two more years than those for the basic plan. The additional operating costs raised the total.

Results of the initial force construction are shown in Table 15 as percent difference from the cost of the basic plan.

TABLE 15

ALTERNATIVE FORCE COSTS, PERCENT OF BASIC PLAN

		Discount Rate		
		0	.10	.15
Alternative 1	1980	-0.3%	-0.4	-0.3
	1990	-0.6	-0.7	-0.6
Alternative 2	1980	+0.4	+1.1	+1.5
	1990	+0.1	+0.8	+1.2

The relative share of costs attributable to ships and aircraft remained essentially constant over the range of discount rates and time periods examined. For carriers and aircraft alone, the ratio was 17% for carriers, 83% for air wings. If each carrier is assigned 4 DLG-type escorts, the breakdown is 12% for carriers, 20% for escorts, and 68% for air wings. It is obvious that the cost of buying and operating the aircraft themselves is the largest part of the systems cost.

Force level adjustment was made to set each alternative equal in cost to the other two alternatives by increasing or decreasing the number of A-7 aircraft purchased in 1972, and continuing

through 1980 (or 1990) with the new force level. Since the America and CVAN-2E classes were primarily involved in the alternatives, the A-7 level was varied only on these ships. The ENTERPRISE was included with the CVAN-2E for air wing composition. In every case it was possible to adjust cost levels without exceeding 100% of deck spot space, or without reducing the coverage below 70%. The resulting forces were then exercised in the two scenarios, with revised aircraft complements for 1973 and 1975. The results are shown in Figures 8 through 15, for the tests conducted. Each figure represents the exercise of each of the three plans at three cost levels, in the two years set, for one scenario.

Consider what these figures represent; in terms of the selected MOE, we have a series of marginal production curves. In effect, these form the <u>supply curves</u> for our three alternatives. The decision-maker is charged with the responsibility for determining the location of the <u>demand curve</u>, and thus arriving at a choice. The calculation of a demand curve is difficult, whether we are talking about industry or the Department of Defense; it is subject to a great deal more uncertainty than our production function, and is often ignored or arbitrarily assumed in order to avoid the difficulty of locating it. In any case, it is not the purpose of this analysis to define the demand curve.

Note the relationship of the three alternatives as costs and time vary. The basic plan is clearly less effective than either alternative, since the HANCOCK-class carrier is much smaller and less effective. The difference between Alternatives One and Two

is less, and changes as the conditions vary, but the pattern is clear. As the nuclear alternative is reduced in cost, its effectiveness is significantly reduced, especially in the 1973 period. However, the conventional-power alternative is able to just match the effectiveness of the nuclear one at the highest cost level, and then only in some of the cases. The slope of the curves illustrates the points discussed in Chapter II for production. If the requirement for Attack Carrier Striking Forces is expected to increase in the future, the nuclear alternative is more capable of expansion than the conventional one. Once again, the location of the demand curve is significant.

One of the factors which affects the capability of the forces in Alternative One at the highest cost level is the reduction in sortie rate caused by high-percentage deck loads. This was discussed in Chapter IV, where it was noted that no study has been made to date of the actual effect. An indication of an alternative adjustment may be found in a sensitivity test made in a recent study. An investigation was made into the cost of placing a CVAN-2E size carrier air wing on an AMERICA-class hull, keeping deck spot percentage constant. The resulting cost for the additional aircraft and hull modifications was greater than the cost differential for the nuclear-powered carrier and air wing.[1]

---

[1]NAVWAG 42, Tactical Air Warfare Study II (U), Vol. III, p. 31 (SECRET).

Another method of setting the alternatives at equal cost would be to change the number of F-111B aircraft purchased. For the 1967-1980 period, 1 F-111B would represent the cost of more than 4 A-7; however, the resulting change in effectiveness could not be evaluated with this model.

Cost of providing nuclear escorts was evaluated by calculating the marginal cost of one DLGN over one DLG of comparable tonnage and armament. Provision of 4 nuclear escorts for a nuclear carrier would mean the elimination of nearly all the A-7 aircraft embarked aboard, if cost is to be held constant. The result would be to reduce effectiveness to an insignificant level, in the model used here. The increase in effectiveness of the force due to increased mobility and reduced vulnerability cannot be evaluated unless a more elaborate model is constructed. Thus no meaningful conclusion can be drawn regarding the true value of nuclear escorts within this study.

The possibility of providing Alternative Two at the same cost as the basic plan still exists. Note that Alternative Two is more effective than the basic plan, even at the same cost level. Testimony by the Secretary of Defense[1] proposed the maintenance of 15 attack carriers with 12 air wings (plus the two refresher training wings); ships in overhaul would release their air wings for use aboard those at sea. This alternative, although not addressed in this study, could result in reduced over-all cost with no reduction

---

[1]U.S., Congress, House, Hearings, 89th Cong., 2nd Sess., 1966, Part 1, p. 150.

in effectiveness, short of an all-out war in which all forces would be committed. It is generally agreed that a war of such magnitude would most certainly be nuclear, and reduced numbers of carrier air wings would not affect the result.

The requirement for support by AE and AOR ships while conducting combat operations was evaluated in Appendix D. Requirements change as a result of distance changes between resupply port and underway replenishment area, generally because more replenishment ships are needed to fill the "pipeline" as distance increases. Percentage differences for the AMERICA-class compared with the CVAN-2E class are shown in Table 16.

TABLE 16

UNDERWAY REPLENISHMENT REQUIREMENTS

AMERICA-CLASS CARRIER

(CVAN-2E = 100%)

URG Distance	1973	1975
750 Miles	112%	116
250 "	101	106
150 "	99.8	104

The major difference is caused by the requirement for NSFO or black oil by the conventional-powered ship. For the 150-mile case in 1973, requirements are slightly less for the AMERICA-class because its ordnance-delivery capability is markedly less, and therefore it requires a much smaller fraction of AE supply.

In summary, as can be seen graphically in Figures 8 - 15, the analysis indicates that Alternatives One and Two are both more effective than the basic plan, under all variations applied to test sensitivity. Alternative One is more effective than Alternative Two at lower cost levels and earlier time-frames, but Alternative Two becomes more effective than Alternative One at high cost levels and later times. The slope of the "supply" curves indicates that the nuclear alternative has more capability of increased expansion in future years.

Nuclear escorts do not appear worth the marginal cost in the framework of this model, but their contribution to effectiveness has not been evaluated. No meaningful conclusion can be drawn because of the limited framework in which they have been examined.

Replenishment ship requirements are less for nuclear carriers than conventional-powered carriers. Ammunition requirements are greater, but fuel requirements are significantly smaller, causing the overall reduction.

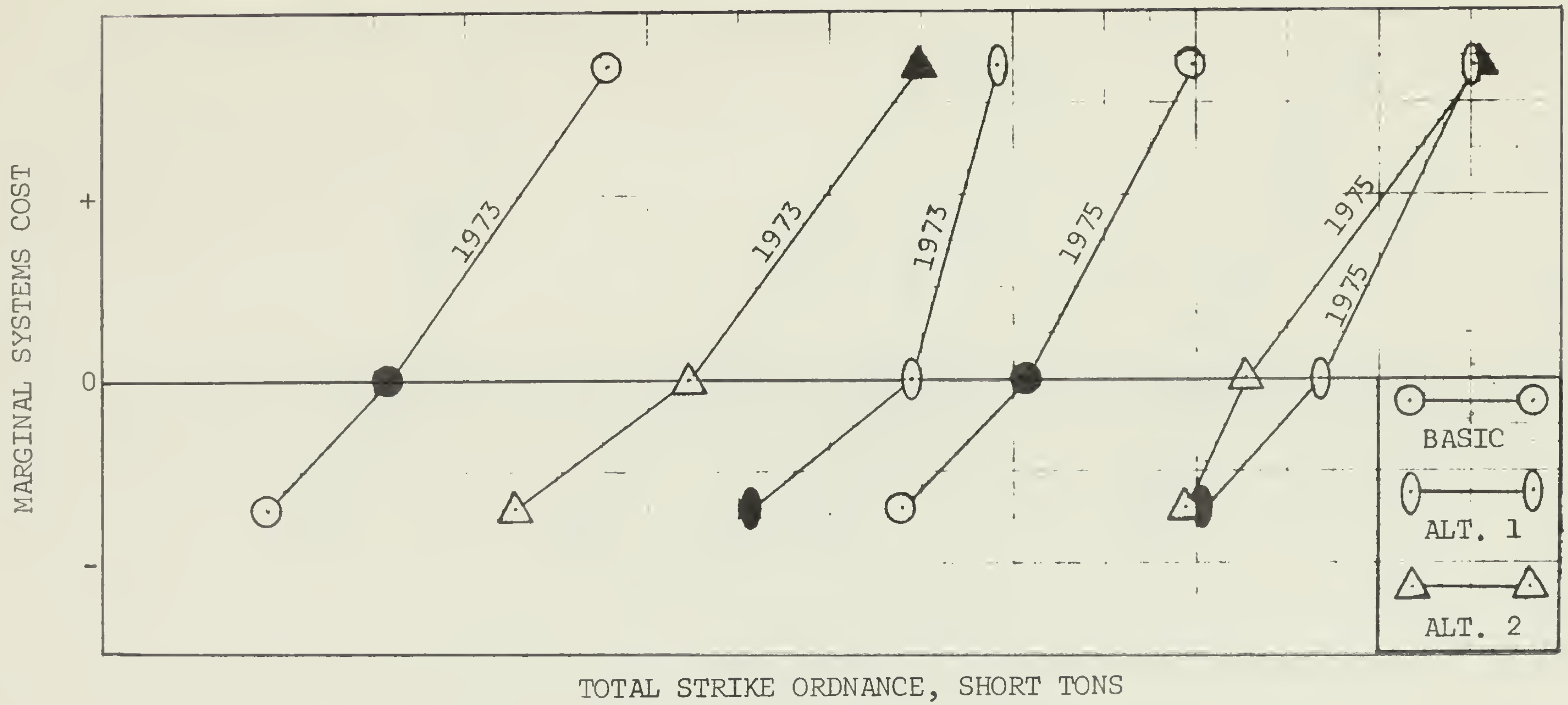
Perhaps the best way to conclude the analysis is to list the alternatives which were not studied, indicating where more work could be done. The vulnerability of the force to enemy opposition has been discussed a number of times. Its evaluation is the subject of continuing study throughout the Department of Defense.

More directly involved are such items as effectiveness of the various fighter complements in air defense and attack groups escort; effect of tanker aircraft and electronic countermeasures (ECM) aircraft in terms of contribution to the mission; capability of the force under bad-weather conditions or darkness; and nuclear delivery capability, if it is called for.

Even a short listing cannot address all the questions which affect the proper force level and force mix for the Attack Carriers. Changes in force level have been studied, as well as substitutes for the force itself. Each of these is pertinent to a particular decision level, and each must be addressed to arrive at the most effective allocation of this Nation's scarce resources in providing for its security. This paper is an attempt to make a small contribution to the success of that allocation.

FIGURE 8

SCENARIO A

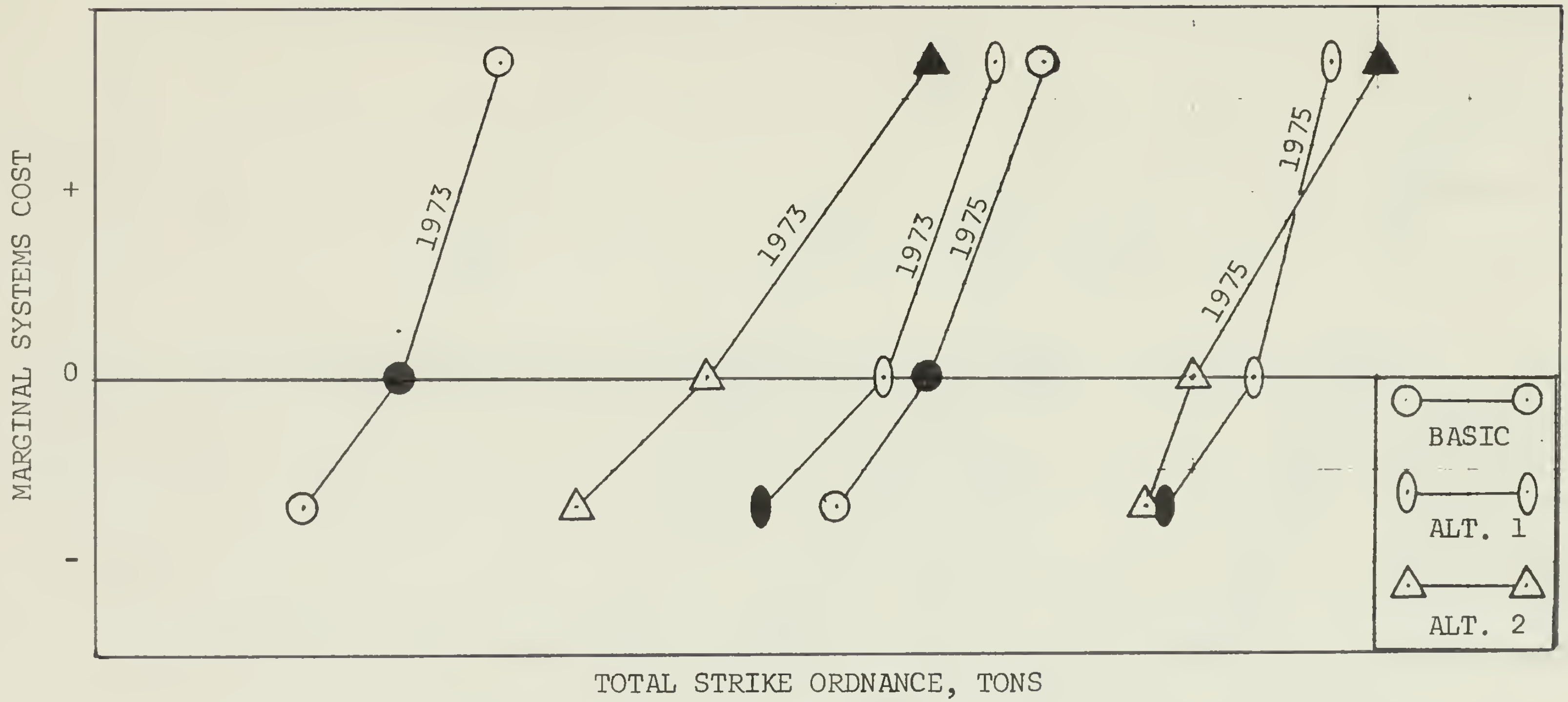


EFFECTIVENESS TEST SUMMARY, 1967-1980, 10%

Note: Solid symbols represent optimum force structures for each alternative.

FIGURE 9

SCENARIO B

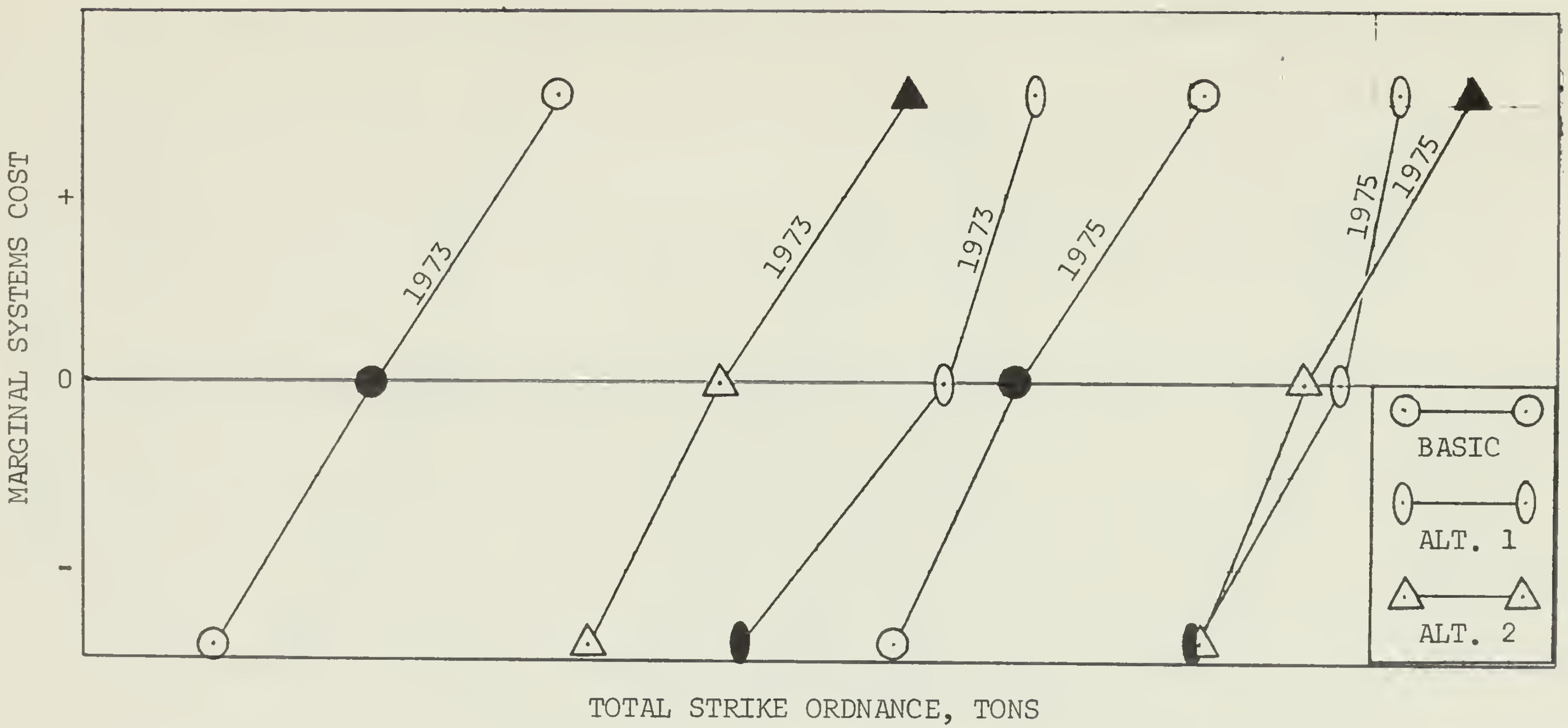


EFFECTIVENESS TEST SUMMARY, 1967-1980, 10%

Note: Solid symbols represent optimum force structures for each alternative.

FIGURE 10

SCENARIO A

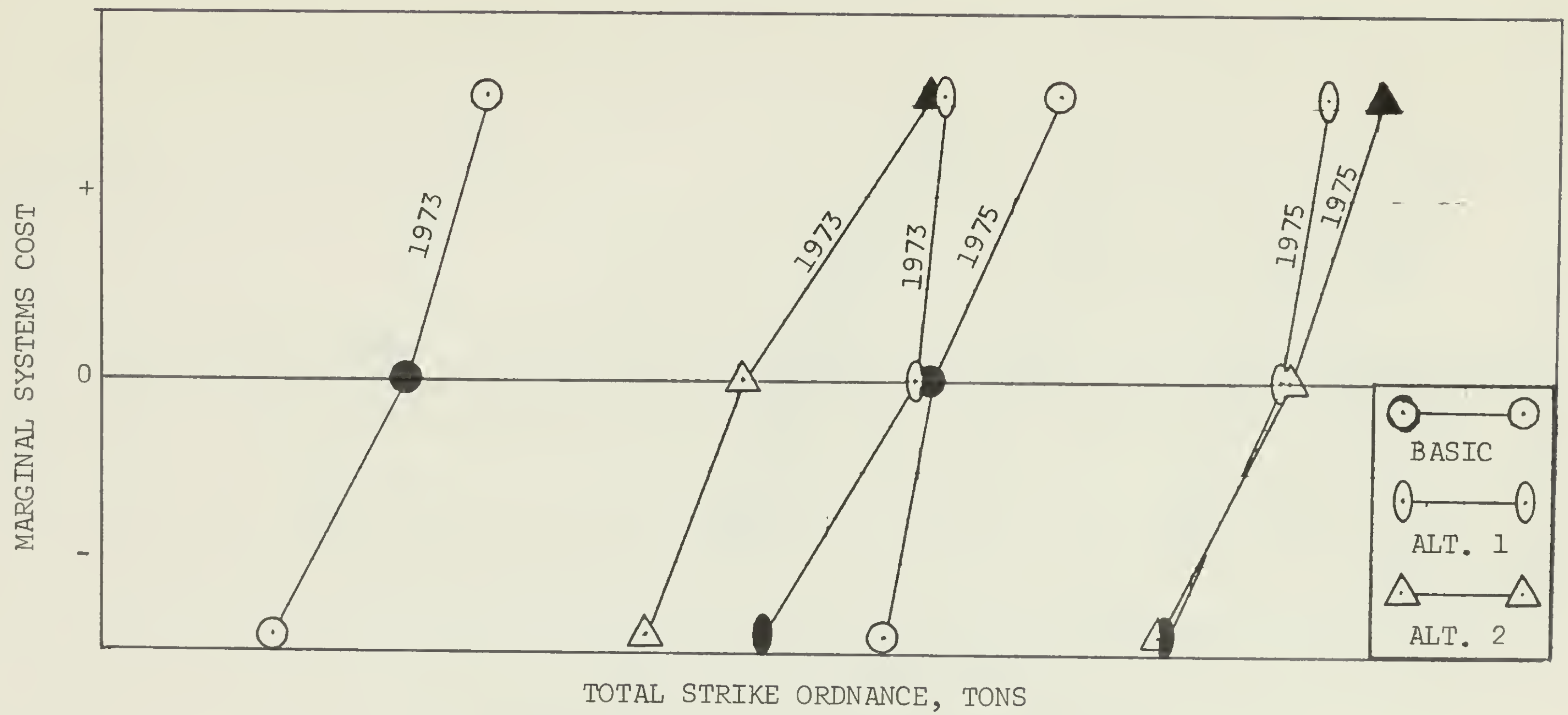


EFFECTIVENESS TEST SUMMARY, 1967-1990, 10%

Note: Solid symbols represent optimum force structures for each alternative.

FIGURE 11

SCENARIO B

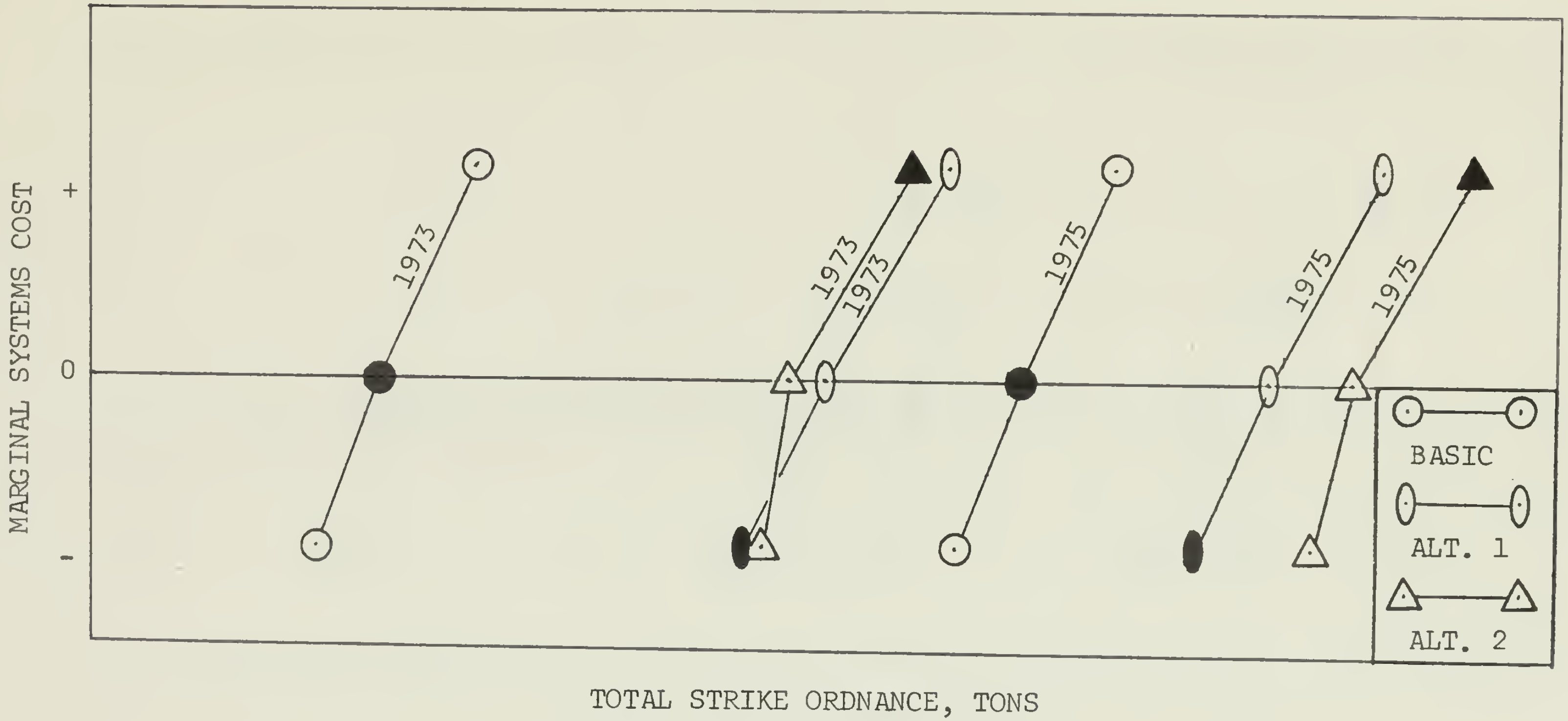


EFFECTIVENESS TEST SUMMARY, 1967-1990, 10%

Note: Solid symbold represent optimum force structures for each alternative.

FIGURE 12

SCENARIO A

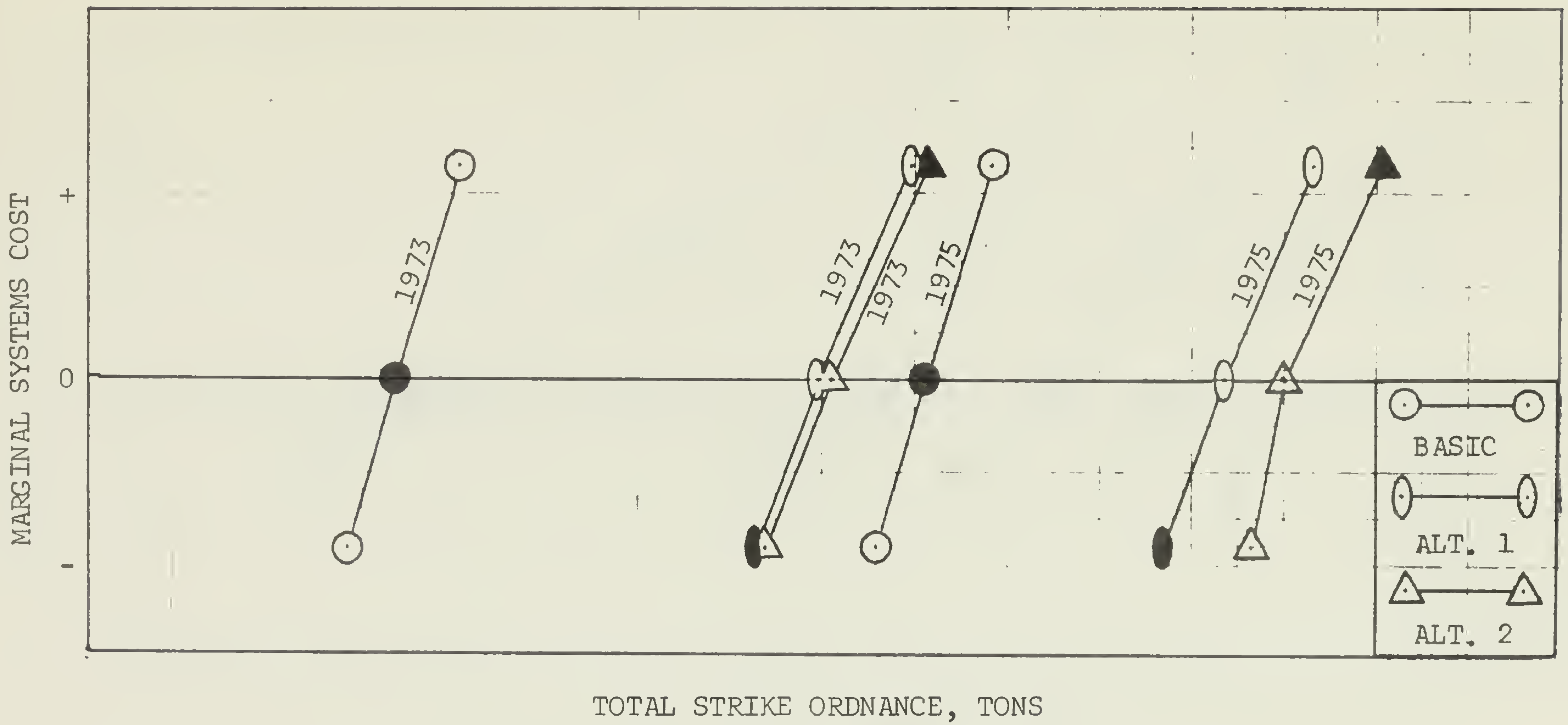


EFFECTIVENESS TEST SUMMARY, 1967-1980, 0%

Note: Solid symbols represent optimum force structures for each alternative.

FIGURE 13

SCENARIO B

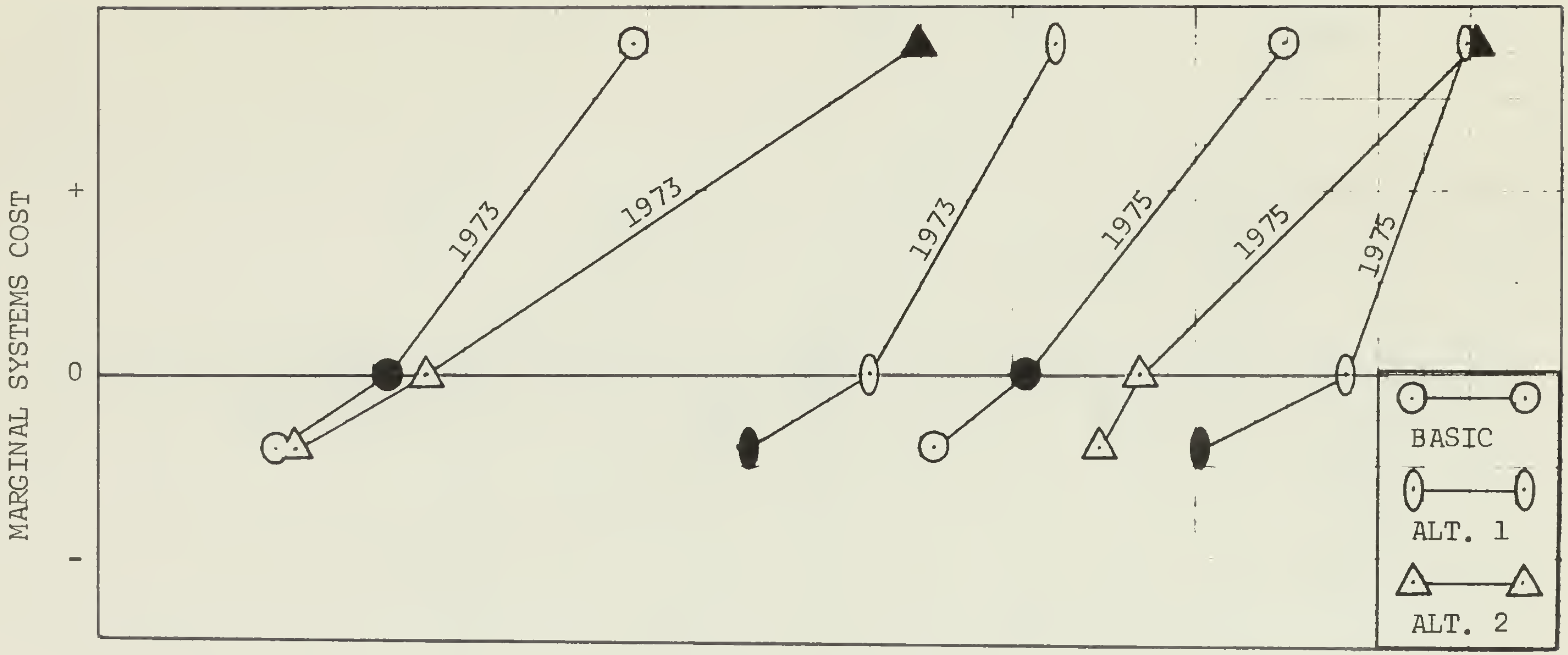


EFFECTIVENESS TEST SUMMARY, 1967-1980, 0%

Note: Solid symbols represent optimum force structures for each alternative.

FIGURE 14

SCENARIO A



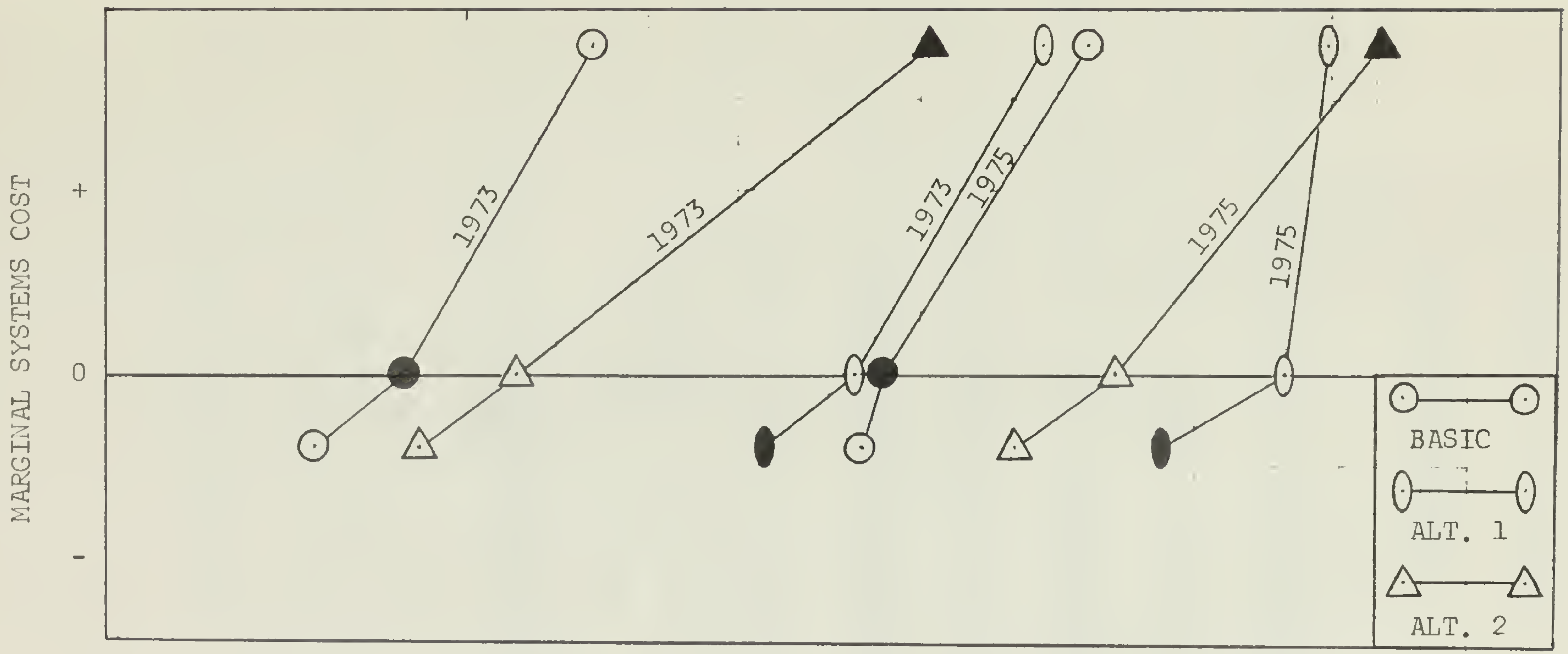
TOTAL STRIKE ORDNANCE, TONS

EFFECTIVENESS TEST SUMMARY, 1967-1980, 15%

Note: Solid symbols represent optimum force structures for each alternative.

FIGURE 15

SCENARIO B



TOTAL STRIKE ORDNANCE, TONS

EFFECTIVENESS TEST SUMMARY, 1967-1980, 15%

Note: Solid symbols represent optimum force structures for each alternative.

SELECTED BIBLIOGRAPHY

Books and Articles

Abert, James G., "Structuring Cost Effectiveness Analyses", Logistics Review and Military Logistics Journal, Vol. II, No. 7, 1966.

Blackman, Raymond V. B. (ed.), Jane's Fighting Ships 1965-1966. New York: McGraw-Hill, 1965.

Breckner, N.V. and Noah, J.V., Costing for Systems Analysis, CNA Research Contribution No. 21. Arlington, Va.: Center for Naval Analyses, The Franklin Institute, 1966.

Clark, J. Maurice, Studies in the Economics of Overhead Costs. Chicago: The University of Chicago Press, 1923.

Fahey, James C. (ed.), The Ships and Aircraft of the U. S. Fleet, eighth edition. Annapolis, Md.: United States Naval Institute, 1965.

Hitch, Charles J. and McKean, Roland N., The Economics of Defense in the Nuclear Age. New York: Atheneum, 1965.

Johnston, J., Econometric Methods. New York: McGraw-Hill, 1963.

Naval Aviation News, January 1965 - July 1966.

Niskanen, William A., Jr., U. S. National Security Objectives and the Choice of Measures of Effectiveness, Internal Note N-30(R), Economic and Political Studies Division, Institute for Defense Analyses. Arlington, Va., 1965.

Reisman, A. and Buffa, E. S., "A General Model for Investment Policy", Management Science, VIII(1962). pp. 304-310.

Suits, Daniel B., Statistics: An Introduction to Quantitative Economics. Chicago: Rand McNally & Co., 1963.

Uhlig, Frank J. (ed.), Naval Review 1962-1963. Annapolis, Md.: United States Naval Institute, 1962.

PUBLIC DOCUMENTS

Unclassified

U. S., Congress, House, Committee on Foreign Affairs, Hearings. 82nd Cong., 2nd Sess., 1952.

U. S., Congress, House, Subcommittee of the Committee on Appropriations, Hearings on the Department of Defense Appropriations for 1966, Part 3. 89th Cong., 1st Sess., 1965.

U. S., Congress, House, Subcommittee of the Committee on Appropriations, Hearings on the Department of Defense Appropriations for 1967, Part 1. 89th Cong., 2nd Sess., 1966.

Classified

BuWeps/BuShips Study W11-13T, Proposed Technical Approach for Improved Aircraft Rearming Rates, 19 Oct, 1964.

Chief of Naval Operations memorandum 00214P05, Navy Objective CVA Air Wing(U). 10 June 1966 (SECRET).

Flight Manual and Performance Supplement (CONFIDENTIAL):

F-4B	NAVWEPS 01-245FDB-1, -1A
RF-4B	NAVWEPS 01-245FDC-1, -1A
F-8E	NAVWEPS 01-45HHD-1, -1A
RF-8A	NAVWEPS 01-45HHB-501, -501A
A-1E	NAVWEPS 01-40ALE-1, -501A
A-3B	NAVWEPS 01-40ATA-1, 40ATD -1A
A-4E	NAVWEPS 01-40AVC-1, -1A
RA-5C	NAVWEPS 01-60ABC-1, -1A
A-6A	NAVWEPS 01-85ADA-1, -1A
EA-6A	NAVWEPS 01-85ADB-1, -1A
E-2A	NAVWEPS 01-85WBA-1
SH-3A	NAVWEPS 01-230HLC-1
C-2A	NAVWEPS 01-85WBB-1
E-1B	NAVWEPS 01-85WAA-1

Naval Aviation Summary, 1 April 1966. Department of the Navy, Office of the Chief of Naval Operations. (SECRET).

Navy Program Factors Book, OPNAV 90P-02. 14 Jan. 1966 (CONFIDENTIAL).

Program Change Proposal, "Modification of F-8 B/C/D/E Aircraft," 1965, approved by Secretary of Defense Memorandum of 25 April 1966. (SECRET).

Public Documents, Classified (cont.)

U. S. Naval Aviation Safety-Center, U. S. Navy Aircraft Accident Statistics (U). FY 55-64. (CONFIDENTIAL).

U. S. Navy Sec Nav 003005 Rated Officer Requirements and Flying Training Programs; Report of Study of Rated Officer Requirements and Flying Training Programs (U). 20 June 1963.

Other Classified Documents

Naval Warfare Analysis Group Study No. 42, Tactical Air Warfare Study II (U). Vol. II, Cost Analysis. Arlington, Va.: Center for Naval Analyses, The Franklin Institute, 1965. (SECRET).

Naval Warfare Analysis Group Study No. 42, Tactical Air Warfare Study II (U). Vol. III, Effectiveness Analysis. Arlington, Va.: Center for Naval Analyses, The Franklin Institute, 1965. (SECRET).

Other Sources

Address by William A. Niskanen, Jr., Director of Special Studies, Office of the Assistant Secretary (Comptroller), Department of Defense to the Joint Conference of the Canadian Operations Research Society and the Operations Research Society of America. Montreal, Canada. 28 May, 1964.

Office of the Chief of Naval Operations. Personal interviews with numerous staff officers. May, 1966 - August, 1966.